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FINAL TECHNICAL REPORT
LORAN D MULTIPLE TOWER TRANSMITTING ANTENNA STUDY AND MODEL TESTING PROGRAM

Sperry Gyroscope
Sperry Rand Corporation
Great Neck, New York

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The use of multi-tower arrays for Loran C and D antennas was investigated since increased power, decreased physical vulnerability, and decreased antenna voltages can be realized. The test was performed on antenna models with a size reduction factor of 100. The measured test data was reduced to antenna and interface information practical for selecting a suitable antenna array, composed of 400-foot towers with top-loading elements forming an umbrella.

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FOREWORD

This final technical report has been prepared as required by item A002 of Exhibit A (Contract Data Requirements List, Item 0002) of Contract Number F19628-74-C-0200, under which Sperry Gyroscope Division, Sperry Rand Corporation, Great Neck, New York, is conducting a study of multiple tower transmitting antennas for Loran D.

The multiple tower antenna study and test program was performed to investigate the feasibility of utilizing multi-tower arrays for Loran C and D antennas. The use of arrays is deemed advantageous since increased power, decreased physical vulnerability and decreased antenna voltages can be realized.

The test of this program was performed with antenna models utilizing a size reduction factor of 100. An open field adjacent to the Sperry plant was utilized as the test site. The tests were performed from October 1974 through May 1975.

Measured test data has been reduced to meaningful antenna parameters yielding antenna and interface information, practical for the selection of a suitable antenna array.

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*Illustrations are grouped at the rear of this report.

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SECTION I

INTRODUCTION

1. PRESENT ANTENNAS

The typical low-frequency Loran D antenna employed has been the top loaded monopole consisting of a guyed tower supported on an insulating base. A capacitive top loading umbrella is utilized to increase bandwidth and radiation efficiency. For tactical reasons the antenna is constructed of light weight metallic sections guyed with non-metallic cabling. Top loading elements consist of 0.312-inch diameter plastic cables covered with metallic braiding and extending 300 to 400 feet toward the ground.

The new AN/TRN-39 Loran D Transmitter will utilize such an antenna, i.e. a 400-foot tower with 12 top loading elements. The single tower antenna is shown in figure 1.

2. OBJECTIVE OF PROGRAM

The multiple tower transmitting antenna study and model test program has as its objective the study and the testing of the effects of combining 2 or 4 monopole antennas of the types presently in use.

The expected advantages of multi-tower operations are:

- Increased radiated power from a given transmitter.
- Lower antenna height for the same radiated power.
- Decreased physical vulnerability through redundancy.

- Increased reliability by permitting partial shutdown without causing loss of on-air time.
- Decreased antenna voltage to increase reliability and permit higher power operation.
- Provide a tactical replacement for larger permanently installed antennas such as the USCG 625-foot Loran C antenna.
- Modular procurement of antenna arrays.
- Simultaneous erection of all towers to reduce total erection time.

The proposed 2 or 4-tower array consists of standard single antenna towers in which the metallic portion of one top-loading element has been extended to a point near the ground. The towers are so arranged that the top loading extensions meet at a central point which is the input to the antenna array.

The proposed 4-tower arrangement, shown in figure 2, is attractive because it fits into the area occupied by a standard USCG 625-foot antenna. Also, the 600-foot distance specified for separation of transmitter and antenna for the AN/TRN-39 will permit placing the transmitter equipment in one of the cusps between top loading guy circles. The 12 top loading elements are interleaved so that no guy is shielding another guy. The lower level support guying (not shown) will also be interleaved and arranged to be mechanically separate.

Either of the diagonal pairs of towers can be used by itself, permitting erection of only two towers or the shutdown of two out of four for maintenenace purposes.

In the proposed arrays, each tower is mechanically and electrically independent. Specifically, the array under study was one which avoids networks of wire between towers either overhead or on the ground.

The proposed antenna configurations were to be tested with the use of well known scale model techniques. These techniques require construction of antenna models, reduced in size by 100/1 from the actual antennas. All the pertinent electrical tests are to be conducted with these models, and the resultant data evaluated. The results are then scaled up to reflect actual full size antenna parameters.

3. PROGRAM PLAN

The multiple tower transmitting antenna study and model test program was directed into four phases:

- Generation of a test plan, fabrication of the required model antennas and the selection of a test site.
- Model testing of existing single towers and multitower arrays. Optimization of various multitower arrays and connections.
- Analysis, data reduction and data evaluation.
- Preparation of a final technical report with conclusions and recommendations.

SECTION II

PRE-TEST PHASE

1. MODEL STUDIES

Model testing to determine the electrical characteristics of large tower antennas is considered the most desirable approach for antenna analysis. It is preferred to mathematical analysis which is complex, and to full size antenna construction which is costly. It also permits a flexible approach permitting modifications to be easily accomplished. In addition, model measurements allow the performance of field strength measurements in a compact small area of uniform ground conductivity relatively close to the location of the model antenna. The latter of course simplifies circular pattern measurements.

The scale factor selected for the program is 100 to 1, requiring the scaling up of the model test frequency from 100 kHz to 10 MHz. To be able to analyze even the largest of the models as a "short vertical radiator" the model must be smaller than 1/8 the wavelength employed ($\lambda/8$)*. Since the tallest antenna employed is 6-1/4 feet and the wavelength is 98.4 feet, the "short antenna" requirement has been met. The relations between actual size and model parameters have been tabulated in table 1.

2. MODEL CONSTRUCTION TECHNIQUES

During the pre-test phase, Sperry constructed six (6) antenna models, four representing the 400-foot tower to be utilized with the AN/TRN-39 transmitter and one each representing the USCG 625-foot tower and the 300-foot AN/TRN-21 antenna.

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*See reference 1, pages 5 and 9.

At a later stage of the program, the program scope was enlarged and four additional models representing 150-foot towers were fabricated. The construction of each model is illustrated in figure 3 and by the photographs in figures 4 and 5. With exception of the top loading and guying element all dimensions have been scaled 100 to 1 from the real antenna dimensions.

A two-foot circular plexiglass base forms the support of the structure. Central to this base is a 3/8-inch diameter brass rod representing the tower. Its lower end is terminated by a BNC connector recessed into the plexiglass base, such that connection to the rod is convenient. The upper end of the rod is hollow, as shown by figure 6, and accommodates either the plastic or the brass bushing shown. The radials or top loading elements shown in figure 7 are soldered to the radial junction plug. When assembled, the bushing, either plastic or brass, fits into the rod and the plug holding the radials fits into the bushing. The tension of the radials guarantees a tight fit. The top loading elements (radials) are AWG 30 beryllium copper wires which terminate in fishing swivels. Nylon fishing line ties the swivels to legs which are attached to the circular base at the required angular spacings. Attachment of the legs to the base is by hinges to permit the folding of the legs for easy transportability.

Scaling of the top loading elements or radials in a 100 to 1 ratio requires 0.00375 diameter wires (AWG 38), deemed too fragile for outdoor model studies. AWG 30 (.010 diameter) wires were therefore used for all models, except for two tests which employed smaller wires.

3. SITE SELECTION

To achieve consistent and meaningful results the site selected for antenna measurement must meet these requirements:

- The field must be large enough such that omnidirectional measurements can be taken several wavelengths away from the antenna location.
- The area must be void of buildings, trees, bushes or other structures which could cause signal bounce or reflections.
- A good ground plane must be provided.

Sperry selected an area approximately 300 by 400 feet, the former site of an extension building which had been demolished in 1972. The location, designated the east field, is adjacent to the engineering offices and meets all the criteria listed above. A map of the field is given in figure 8.

To ascertain that the site was electrically "quiet", field intensity measurements were made at various locations. These indicated interferences at least 30 dB below the expected model field intensity levels.

TABLE 1. SCALE FACTORS

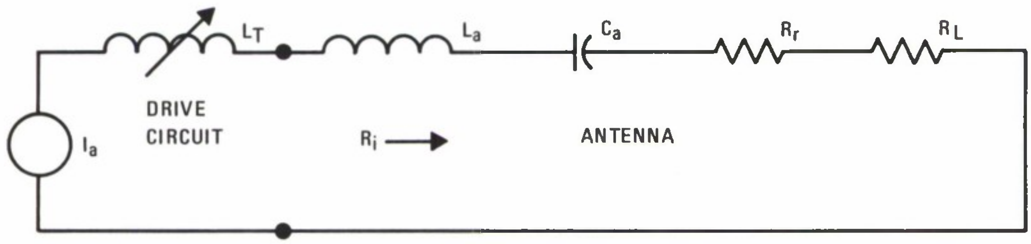
Parameter	Actual Antenna	Model Antenna
Linear Dimensions	1	1/100
Frequency	f	100f
Wavelength	λ	$\lambda/100$
Capacitance	C	C/100
Inductance	L	L/100
Reactance	X	X
Radiation Resistance	R_r	R_r
Input Resistance	R_i	Indeterminate
Intrinsic Bandwidth	Δf	$100\Delta f$

SECTION III

TEST PHASE

1. PURPOSE

"Short" vertical radiators of the type being investigated exhibit electrical properties described by the equivalent series RLC circuit shown below.



The circuit is shown driven from current generator I_a via a tuning inductor L_T, the latter augmenting L_a in establishing a resonant condition at the operating frequency. Each antenna configuration is fully characterized by parameters L_a, C_a, R_r, R_L. Two types of tests are necessary to measure these quantities: an input impedance measurement to derive L_a, C_a and $(R_r + R_L)$, and field strength measurements to yield the quantity R_r. Accordingly, the test phase consisted of making these measurements on every configuration and variation thereof showing promise.

2. TEST SET-UP AND PROCEDURES

a. Impedance Measurements

Impedance measurements were performed by situating the antenna models on top of a wooden table. The table top or platform, 16 x 16 feet, was surfaced with

1/16-inch aluminum sheets joined to form an integral metallic ground plane (figure 9). The impedance measuring test equipment was located under the table to shield the antenna from test equipment radiation and to permit close proximity of the RF bridge employed in the measurement to the antenna input terminal (see figure 10). The set up utilized for impedance measurements is illustrated in block form in figure 11. A General Radio Impedance Bridge Type 916A was connected to the antenna input, physcially located above it, via a hole in the table. Bridge Oscillator GR 1330 provided the measuring signal whereas Field Intensity Meter NF105 was the nulled signal detector. Frequency measurement was performed with Hewlett-Packard Counter HP 5245L.

During the earlier stages of the test phase a Hallicrafter receiver with loud-speaker was utilized as the null detector. It was discovered that the field meter, being an extremely sensitive frequency selective voltmeter, provided superior visual null indication. Consequently, the NF105 was substituted for the radio receiver.

The General Radio Type 916-A Radio Frequency Bridge is a nulling device utilizing a series substitution method. A measurement was made by first balancing the bridge with the "unknown" terminal short circuited, then rebalancing with the short circuit removed and the antenna connected to the "unknown" terminal. The unknown reactance and resistance are then equal to the change in reactance or resistance dial readings. The reactance dial reading was divided by the frequency in MHz, while the resistance reading was directly read from its dial. Accuracy for reactance is specified as $\pm(2\% + 1 \text{ ohm} + 0.0008 \times R \times f)$ where R is the measured resistance in ohms and f is the frequency in MHz.

To minimize errors, the unknown terminal must be as close as possible to the antenna input, and the position with respect to ground of the short connecting wire between bridge and antenna must not change between the two nulling operations. Input impedance was measured as a function of frequency for all the important antenna configurations. It will be shown later that the slope and input reactance at 10 MHz are the important parameters required to determine the antenna capacity and inductance. Minimum and maximum readings are required to determine series and parallel self resonance.

b. Field Strength Measurements

The radiation efficiency expressed by radiation resistance R_r is determined by injecting a known quantity of 10 MHz r-f current into the antenna configuration and measuring at some distance the amount of radiated field present. Figure 12 illustrates the set-up of the test equipment to perform field strength measurements. The antenna model is situated near the center of the test site on the ground. It is driven from a Type 230-A Boonton Amplifier situated 125 feet away via a coaxial line. Input to the amplifier is from GR Bridge Oscillator 1330A. Constant frequency is monitored with Frequency Counter HP 5245L.

Antenna current is measured with a Model 110 Pearson Wide-Band Current Transformer by passing the antenna input wire through the current transformer and observing the secondary voltage generated (proportional to the antenna current) with a True Rms Voltmeter Ballantine Model 323 located 110 feet from the antenna. The current transformer is further described in Appendix I.

Located at a measured distance from the transmitting antenna model is Field Intensity Meter Model NF105 with its loop antenna LP-105. When rotated in line with the transmitting antenna, the loop picks up the transmitted signal, which is conducted to the main frame via a 30-foot coaxial cable. The electronics in the main frame of the field intensity meter amplify and measure the received signal. To this measurement are added the loop antenna and cable loss factors. The resultant number is the field strength at the loop antenna location. Calibration curves for the devices are given in Appendix II.

Field Intensity Meter NF105 is self calibrating, inasmuch as it contains a known reference voltage used to adjust the gain prior to each field intensity measurement.

Computation of radiation resistance requires the measurement of antenna current, field strength and distance from transmitting to loop antenna. Determination of the radiation pattern requires these measurements to be made at a constant distance and constant current, but from a different direction. Measurements from eight directions (every 45^o) were generally made to establish the radiation pattern. Performance of the field strength measurements required authorization from the FCC to radiate at 10 MHz and at specified harmonics. This authorization was duly received and is included in this report as Appendix VI.

3. CONFIGURATIONS

Impedance and radiation measurements were made for the various antenna configurations tabulated in table 2. Initially the standard tower configuration for the 3-, 4- and 6.25-foot antennas were measured and the results compared with the known full scale parameters, table 3. When this comparison proved correct, the results were used as a base line and confidence factor to proceed with the multiple tower configurations. All multi-array configurations in table 2, with the exception of 24, 29, 30, 31 and 32 are arranged as in figure 2. In configuration 24, each antenna was moved toward the center or feed point; in configurations 29, 30, 31 and 32, each antenna was moved away from the center feed point.

TABLE 2. ANTENNA CONFIGURATIONS

No.	Antenna Height (ft)	Number of Antennas	Number of Active Antennas	Feed	Rod Connection: Base to Gnd	Rod Connection: Top to Radials	Impedance Data: Table	Impedance Data: Log[a]	Radiation Data: Table	Radiation Data: Log[a]	Remarks
1	3	1	1	rod	ins[b]	cond[c]	4	1-18	6	2-11	Std. 3-ft antenna
2	6.25	1	1	rod	ins	cond	4	1-19	6	1-38	Std. 6.25-ft antenna
3	4	1	1	rod	ins	cond	4	1-40	6	2-11	Std. 4-ft antenna
4	4	1	1	slant	cond	ins	4	1-41	6	1-46	
5	4	1	1	slant	ins	cond	4	1-41	6	2-13	
6	4	1	1	slant	ins	ins	4	2-21	-	-	#41 wire top loading
7	4	1	1	slant	cond	ins	4	2-20	-	-	#41 wire top loading
8	4	1	1	slant	cond	ins	4	1-42	6	1-45	Feed into 2 radials
9	4	1	1	slant	cond	ins	4	2-17	-	-	Feed wire is #41 for impedance
10	4	1	1	slant	ins	ins	4	2-17	6	2-12	Feed wire is #41 for impedance
11	4	1	1	slant	ins	cond	-	-	6	2-12	9 1-1/2-ft radials
12	4	1	1	slant	ins	ins	-	-	6	2-12	9 1-1/2-ft radials
13	4	2	2	slant	cond	ins	4	2-5	6	2-7	
14	4	2	2	slant	ins	cond	4	2-4	6	2-13	
15	4	2	2	slant	ins	ins	4	2-24	6	2-14	
16	4	2	1	slant	ins	cond	-	-	-	-	Induced measurements
17	4	2	1	slant	cond	ins	-	-	-	-	Induced measurements

[a]Log 1-2 means log 1, page 2 (Appendix VII).
[b]insulated
[c]conducting

TABLE 2. ANTENNA CONFIGURATIONS (cont.)

No.	Antenna Height (ft)	Number of Antennas	Number of Active Antennas	Feed	Rod Connection: Base to Gnd	Rod Connection: Top to Radials	Impedance Data: Table	Impedance Data: Log[a]	Radiation Data: Table	Radiation Data: Log[a]	Remarks
18	4	3	2	slant	ins[b]	cond[c]	4	2-4	6	2-7	Input to inactive antenna grounded
19	4	3	2	slant	cond	ins	4	2-5	-	-	
20	4	3	2	slant	ins	ins	-	-	-	-	Induced measurements
21	4	4	4	slant	cond	ins	4	1-48	6	2-9	
22	4	4	4	slant	ins	cond	4	2-4	6	2-8	
23	4	4	4	slant	ins	ins	4	2-26	6	2-22	
24	4	4	4	slant	ins	cond	-	-	6	2-10	Close proximity
25	4	4	2	slant	cond	ins	4	1-48	-	-	2 diagonal tower feeds open
26	4	4	2	slant	cond	ins	4	1-49	6	2-9	2 diagonal tower feeds grounded
27	4	4	2	slant	cond	ins	4	1-49	-	-	2 adjacent tower feeds grounded
28	4	4	2	slant	ins	cond	4	2-4	-	-	2 diagonal tower feeds grounded
29	4	4	4	slant	ins	ins	4	2-28	6	2-29	22-ft dia.circle
30	4	4	4	slant	ins	ins	4	2-28	-	-	20-ft dia.circle
31	1.5	4	4	slant	ins	ins	4	2-30	6	2-31	8.25-ft dia.circle
32	1.5	4	4	slant	ins	cond	-	-	6	2-32	8.25-ft dia.circle

[a] Log 1-2 means log 1, page 2 (Appendix VII).
[b] insulated
[c] conducting

TABLE 3. ANTENNA PARAMETERS FROM FIELD DATA (FULL SCALE VALUES)

Configuration	X_i (-j ohms)	R_i (ohms)	C_a (pf)	L_a (mH)	f_{sr} (kHz)	R_r (ohms)	Δf (kHz)
300-Foot Loran-D Antenna	334	4.1	3,900	121	275	0.49	0.120
400-Foot Loran-D Antenna	207	4.0	5,600	122	215	1.07	0.376
USCG 625-Foot Loran-C Antenna	25	2.5	11,000	190	107	2.10	1.727

SECTION IV

ANALYSIS AND DATA REDUCTION

1. DETERMINATION OF ANTENNA REACTANCES FROM IMPEDANCE MEASUREMENTS

Antenna reactances, and therefore capacitance and inductance for each configuration, have been computed from input impedance bridge measurements. With the assumption of a series RLC circuit the capacitive reactance is (see Appendix III):

$$Xc = \frac{f_o \left(\frac{dX_i}{df}\right)_{f_o} - X_o}{2} \tag{1}$$

The inductive reactance is:

$$X_{L_a} = X_o - X_{C_a} \tag{2}$$

where

$\frac{dX_i}{df}$ = input reactance slope of the antenna, ohms/Hertz, at 10 MHz

X_o = input reactance of the antenna, j ohms at 10 MHz

X_{C_a} = antenna capacitive reactance, j ohms at 10 MHz

X_{L_a} = antenna inductance reactance, j ohms at 10 MHz

f_o = 10 MHz

Antenna capacitance and inductance are then calculated from the standard formulas:

$$C_a = \frac{1}{2\pi f X_{C_a}} \tag{3}$$

and

$$L_a = \frac{X_{L_a}}{2\pi f} \tag{4}$$

The input impedance measurement results are listed in table 4 for all the configuration of interest. The input reactance for a number of these has been plotted in figures 13 through 22. The antenna capacitance and inductance calculated from the data have been tabulated in table 5.

2. RADIATION RESISTANCE FROM FIELD STRENGTH MEASUREMENTS

Radiation resistance has been computed utilizing the formula for radiated power at a point d miles from the radiating source:

$$P_{kW} = \left[\frac{(Ed)}{(186.4)}\right]^2 \text{(see Appendix VI)} \tag{5}$$

where E is in millivolts/meter

d is in miles

P_{kW} is radiated power in kilowatts

186.4 = conversion factor (see Appendix VI)

Since Power $P = I_a^2 R_r$ watts (6)

where

R_r = radiation resistance in ohms

I_a = Antenna input current, in amperes

it follows that

$$I_a^2 R_r = \left[\frac{(Ed)}{(186.4)}\right]^2 \tag{7}$$

and

$$R_r = \left[\frac{(Ed)}{(I_a\ 186.4)}\right]^2 \times 10^3 \tag{8}$$

TABLE 4. ANTENNA IMPEDANCE MEASUREMENTS SUMMARY

FREQ (MHz)	Configuration 1		2		3		4		5		6		7		8		9		10		13		14	
	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i
3.75																					-293	.45	-306	.35
4											-688	7.9	-595	8.8			-525	6.4	-575	5.8				
5																					-190	.5	-200	.75
6											-370	7.8	-327	7.5			-267	6.9	-325	6.4				
7																					-107	.75	-114	.6
8											-206	8.4	-168	8.4			-112.5	8.2	-156	7.5				
9	-287	≈1	-37	1	-211	0	-86.7	2.2	-100	2.4	-137	9.0	-100	9.2	-127.8	.7	-55	9.4	-94	6.3	-44	1.3	-56	1.1
10	-257	≈1	-16	2	-180	0	-38	3.6	-45	3.6	-80	10.0	-45	10	-95	1.0	0	10.5	-40	9.8	-20	1.6	-30	1.6
11	-220	≈1	+10	3.6	-150	0	+9.1	3.0	0	3.1	-35	11.0	0	11	-70.4	1.2	+50	11.6	+15	11.2	0	1.9	-5	1.85
12																								
13											+70	14.5	+105	14.7										
14															0	5					+67	2.6	+61	3.3
15											+175	20	+233	20.1			+280	21.5	+233	22				
16																			+300	28.5				
17																								
18											+320	-												
19																								
20													+400	-							+235	11.0		
22																								

Note: X_i values are in j ohms; R_i values are in ohms.

TABLE 4. ANTENNA IMPEDANCE MEASUREMENTS SUMMARY (cont)

FREQ (MHz)	Configuration 15		18		19		21		22 & 28		23		25		26		27		29		30		31	
	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i	X_i	R_i
3.75			-306	.35	-280	.55	-160	.4	-171	.6			-280	.6	-280	.3	-293	0						
4	-288	.6									-155	.70									-150	.8	-400	0
5			-200	.75	-190	.55	-110	.48	-116	.45			-190	.6	-190	.35	-200	.3						
6	-158	1.1									-92	.85									-75	.6	-250	0
7			-114	.60	-107	.6	-57	.5	-64	.7			-100	.8	-100	.5	-107	.6						
8	-81	1.6									-50	1.3									-38	1.3	-177	0
9	-56	2.0	-56	1.1	-44	1.35	-22	.95	-28	1.05	-33	1.6	-44	1.3	-44	1.1	-44	1.1	-11	2.2	-19	1.7	-150	0
10	-25	2.4	-30	1.6	-25	1.65	-10	1.15	-15	1.4	-15	2.0	-20	1.6	-20	1.7	-22	1.7	+7.6	2.8	-2	2.0	-130	0
11	0	2.9	-5	1.85	-2	1.85			+2	1.75	+2	2.2	+5	1.9	+5	1.5	+1	2.4	+17	2.8	+13	4.5	-114	0
12	+18	4.2					+18	1.75			+13	4.6	+26	2.4							+21	3.1	-98	0
13																								
14	+61	4.9	+61	3.3	+68	2.55			+375	2.85	+40	3.8			+70	2.6	+70	3.4			+54	5.0	-75	0
15							+51	3.2					+120	4.4										
16	+109	7.9									+58	5.6											-56	0.2
17	+132	6.8																			+81	7.1		
18	+172	4.5									+92	7.6											-39	1.0
19	+221	6.4																						
20	+240	15.5					+125	8.0			+121	6.1	+240	11.5							+165	15.0	-25	1.2
22	+262	-									+177	17.0									+227	26.5	-7	2.1

Note: X_i values are in j ohms; R_i values are in ohms

TABLE 5. CALCULATED ANTENNA MODEL PARAMETERS

Config. No.	Height (ft)	No. of Towers	X_i (ohms)	R_i (ohms)	C_a (pF)	L_a (μH)	(MHz)	R_r (ohms)	Δf (kHz)	Δf (relative to std. 4-ft antenna)
1	3	1	-257	1.0	54	0.61	28.0	0.32	10.8	0.28
2	6.25	1	-16	2.0	127	1.7	10.9	2.48	197.8	5.16
3	4	1	-180	0	65.5	0.91	19.5	0.93	38.3	1
4	4	1	-38	3.6	61.6	3.51	10.9	0.38	14.7	0.38
5	4	1	-45	3.6	58.4	3.62	11.0	0.63	23.1	0.60
10	4	1	-40	9.8	54	4.06	10.7	0.73	24.8	0.65
13	4	2	-20	1.6	132	1.59	11.0	0.53	43.9	1.15
14	4	2	-30	1.4	114	1.75	11.0	0.76	54.4	1.42
15	4	2	-25	2.4	106	1.99	11.0	0.87	57.9	1.51
21	4	4	-10	1.15	223	0.97	10.5	0.41	57.4	1.50
22	4	4	-15	1.40	193	1.07	11.0	0.58	70.3	1.84
23	4	4	-15	2.0	172	1.23	11.0	0.70	75.6	1.97
29	4	4	+8	2.8	240	1.17	9.7	0.84	126.6	3.30
31	1.5	4	-130	0	103	0.39	22.0	0.10	6.5	0.17

Note: X_i values are in j ohms.

Formula (8) is applied for each field intensity measurement by substituting in it:

- The measured distance in miles between the model antenna and field intensity meter
- The field meter reading modified by the meter and loop correction factors. The loop correction factor including cable loss is 42 dB at 10 MHz. The field intensity in dB above one microvolt per meter is converted to millivolts per meter.
- The current transformer output voltage divided by the factor 47 mV per ampere which yields the antenna current in amperes. The factor 47 mV/amperes includes a cable loss of 1.5 dB.

For the significant antenna configurations, measurements were made at varying distances d to establish that operation actually was taking place in the far field. Circular measurements were then made at constant radius d, with a constant antenna current (±5%) and at eight different azimuths. These measurements in terms of field strength (dB above one microvolt per meter) are given in figures 23 through 32 and indicate the omnidirectional reception pattern which can be expected.

Field strength and computed radiation resistance for each direction are listed in table 6. To arrive at the final radiation resistance for each configuration, the individual resistance values were averaged and are listed in table 5.

3. INTRINSIC BANDWIDTH FOR VARIOUS CONFIGURATIONS

For Loran pulse systems the intrinsic bandwidth Δf is the important antenna criterion, for it determines the ability of the antenna to radiate maximum sampling point power, and it is to be maximized. The intrinsic bandwidth is derived from single series tuned circuit theory in Appendix V:

$$\Delta f = \frac{2 R_r}{\frac{dX_i}{df(f_o)} - \frac{X_i}{f_o}} = 2 \pi f_o{}^2 R_r C_a$$

Values for Δf have been calculated from the capacitance and resistance for each important configuration and appear in table 5.

TABLE 6. FIELD INTENSITY MEASUREMENTS SUMMARY

Antenna Configuration	Azimuth (degrees)	Input Current (amps)	Distance (ft)	Field Intensity E (dB above 1 μV/meter)	Field Intensity E (μV/meter)	Radiation Resistance (ohms)
1	90	0.146	200	82.5	13.34	0.35
	135	0.146	200	81.8	12.3	0.29
2	45	0.046	205	80.8	11.0	2.48
3	0	0.238	200	90.2	32.36	0.76
	45	0.236	200	92	39.81	1.17
	90	0.236	200	91.4	37.15	1.02
	135	0.236	200	90.5	33.50	0.83
	180	0.229	200	89.9	31.26	0.76
	225	0.229	200	91.2	36.31	1.03
	270	0.240	200	90.6	33.88	0.82
	315	0.240	200	91.7	38.46	1.06
4	45	0.270	208	88.0	25.12	0.38
5	0	0.226	200	89.5	29.85	0.72
	45	0.227	200	89.2	28.84	0.66
	90	0.226	200	88.9	27.86	0.63
	135	0.226	200	88.1	25.41	0.52
8	45	0.172	208	83.5	15.2	0.35
10	0	0.229	200	89.5	29.85	0.69
	45	0.229	200	90.2	32.36	0.82
	90	0.232	200	90.0	31.62	0.77
	135	0.234	200	89.4	29.52	0.66
	135	0.234	200	89.6	30.20	0.69
	135	0.234	150	91.9	39.35	0.66
	135	0.234	250	87.7	24.27	0.69
11	45	0.240	200	91.1	35.89	0.92
	90	0.240	200	91.0	35.48	0.90
	135	0.242	200	90.5	33.50	0.79
12	45	0.234	200	91.4	37.15	1.04
	90	0.234	200	91.4	37.15	1.04
	135	0.234	200	90.8	34.67	0.91
	135	0.234	250	89.0	28.18	0.94
13	0	0.242	200	88.3	26.01	0.48
	45	0.238	200	88.5	26.61	0.51
	90	0.240	200	88.6	26.92	0.50
	135	0.236	200	88.9	27.86	0.57
	180	0.244	200	88.8	27.54	0.52
	225	0.244	200	89.8	30.90	0.66
	270	0.240	200	87.9	24.83	0.45
	315	0.244	200	89.2	28.84	0.57

TABLE 6. FIELD INTENSITY MEASUREMENTS SUMMARY (cont.)

Antenna Configuration	Azimuth (degrees)	Input Current (amps)	Distance (ft)	Field Intensity E (dB above 1 μV/meter)	Field Intensity E (μV/meter)	Radiation Resistance (ohms)
14	0	0.238	200	90.0	31.62	0.73
	45	0.244	200	90.4	33.11	0.76
	90	0.242	200	90.2	32.36	0.73
	135	0.242	200	89.2	28.84	0.58
	180	0.238	200	90.2	32.36	0.76
	225	0.238	200	90.7	34.28	0.85
	270	0.238	200	90.2	32.36	0.76
	315	0.238	200	90.9	35.08	0.89
15	0	0.232	200	89.7	30.55	0.71
	45	0.232	200	91.0	35.48	0.96
	90	0.234	200	90.9	35.09	0.93
	135	0.234	200	89.7	30.55	0.70
	180	0.229	200	90.6	33.88	0.89
	225	0.229	200	90.8	34.67	0.94
	270	0.232	200	90.2	31.99	0.78
	315	0.232	200	91.4	37.15	1.05
18	0	0.232	200	88.8	27.54	0.58
	45	0.234	200	88.0	25.12	0.48
	90	0.234	200	88.1	25.41	0.49
	135	0.229	200	87.9	24.83	0.48
	180	0.229	200	87.3	23.17	0.42
	225	0.229	200	88.8	27.54	0.59
	270	0.229	200	86.9	22.14	0.38
	315	0.227	200	90.0	31.62	0.80
21	0	0.232	200	87.6	23.99	0.44
	45	0.240	200	87.4	23.44	0.39
	90	0.232	200	87.3	23.17	0.41
	135	0.232	200	86.7	21.63	0.36
	180	0.232	200	87.0	22.39	0.38
	225	0.232	200	87.6	23.99	0.44
	270	0.232	200	86.7	21.63	0.36
	315	0.232	200	88.1	25.41	0.50
22	0	0.242	200	89.0	28.18	0.56
	45	0.244	200	89.4	29.51	0.60
	90	0.244	150	90.9	35.08	0.48
	90	0.244	200	89.0	28.18	0.55
	90	0.244	250	88.1	25.41	0.69
	135	0.244	200	88.8	27.54	0.52
	180	0.244	200	88.9	27.86	0.54
	225	0.244	200	89.2	28.84	0.57
	270	0.246	200	88.6	26.92	0.49
	315	0.242	200	90.5	33.50	0.78

TABLE 6. FIELD INTENSITY MEASUREMENTS SUMMARY (cont.)

Antenna Configuration	Azimuth (degrees)	Input Current (amps)	Distance (ft)	Field Intensity E (dB above 1 μV/meter)	Field Intensity E (μV/meter)	Radiation Resistance (ohms)
23	0	0.240	200	89.7	30.55	0.67
	45	0.240	200	90.0	31.62	0.71
	90	0.240	200	90.1	31.94	0.73
	135	0.240	200	89.2	28.84	0.59
	135	0.244	200	89.6	30.20	0.65
	135	0.244	250	87.5	23.75	0.61
	135	0.244	300	85.7	19.28	0.57
	180	0.244	200	89.8	30.90	0.66
	225	0.240	200	90.9	35.08	0.88
	270	0.240	200	88.3	26.01	0.48
	315	0.240	200	90.8	34.67	0.86
24	135	0.244	200	89.0	28.18	0.54
26	0	0.244	200	87.0	22.39	0.35
	45	0.244	200	87.0	22.39	0.35
	90	0.244	200	87.2	22.91	0.36
	135	0.244	200	85.2	18.20	0.23
	180	0.244	200	85.0	17.78	0.22
29	0	0.234	200	90.1	31.99	0.77
	45	0.234	200	90.6	33.88	0.87
	90	0.234	200	90.1	31.99	0.77
	135	0.234	200	89.6	30.20	0.69
	157.5	0.234	200	90.3	32.73	0.81
	180	0.234	200	91.0	35.48	0.75
	225	0.234	200	91.2	36.31	0.99
	270	0.234	200	89.8	30.90	0.72
	315	0.234	200	91.0	35.48	0.95
31	0	0.238	200	81.5	11.89	0.103
	45	0.238	200	81.2	11.48	0.096
	90	0.238	200	80.5	10.59	0.082
	135	0.238	200	80.6	10.72	0.084
	180	0.238	200	80.2	10.23	0.076
	225	0.238	200	81.4	11.75	0.100
	270	0.238	200	81.6	12.02	0.105
	315	0.238	200	82.1	12.74	0.118
32	0	0.238	200	81.3	11.22	0.092
	45	0.238	200	80.3	10.35	0.078
	90	0.238	200	80.1	10.12	0.074
	135	0.238	200	79.5	9.44	0.065
	180	0.238	200	80.0	10.00	0.073
	225	0.238	200	81.7	12.16	0.108
	270	0.238	200	81.3	11.62	0.098
	315	0.238	200	81.8	12.3	0.110

4. RESONANT FREQUENCIES

Each antenna configuration exhibits two resonant frequencies, series and parallel. The significant one of these is the series resonant frequency, f_{sr}, which is obtained from antenna input reactance bridge measurements. At f_{sr}, $X_{La} = X_{Ca}$, thus the input reactance is zero. It is important that the antenna model resonate above 10 MHz (100 kHz full scale), otherwise the antenna must be driven via a capacitive element. Driving the antenna in this manner causes transmitter energy transfer not only to the antenna, but also to the capacitive drive element in which, in effect, it is wasted. Consequently, for a given capacitance the inductance must be held to a level at which resonance occurs above 10 MHz. Preliminary measurements and prior studies (reference 3) indicated that the inductance of the top hat is negligible and that the inductive term of the input impedance is due entirely to inductance of the conductor from the feed point to the junction of all top loading elements. Because it was not practical to correctly scale the slant feed wires for all configurations, a single slant-fed tower with AWG 41 wire (0.0025" diameter) was measured and the series resonant frequency obtained was used to study the inductance effect for the more complex configurations. The actual measured series resonant frequencies as read from the reactance graphs in figures 13 through 22 are presented in table 5 for all the configurations of interest. The resonant frequencies measured and listed in table 5 have only been used for interpretation and guidance, whereas the actual resonant frequency will be based on a calculation of the actual slant-feed cable employed with the full size antenna.

Attempts were made to establish the parallel resonant frequencies of the antenna models, but these fell outside the direct reading range of the impedance bridge. The range of the bridge was then extended by means of an auxiliary capacitor to readings up to 30 MHz. At 23 MHz the integrity of the test set-up started to deteriorate as evidenced by poor nulls. Readings were, therefore, only taken up to 23 MHz, in order to devote more attention to the primary objectives of the program.

5. HARMONIC RADIATION EFFICIENCY

Harmonic frequency testing was limited to radiation measurements at the second and third harmonics of the 10 MHz model frequency. Beyond these frequencies, the one-eighth wavelength ($\lambda/8$) of the excitation frequencies begins to exceed the

antenna dimension, complicating the analysis in terms of radiation resistance. Harmonic radiation resistance is calculated in the same manner as for the fundamental frequency, described in section IV paragraph 2. For 20 and 30 MHz, the loop antenna factor is 40 and 38 dB respectively, and the loop antenna cable loss equals 0.6 and 0.7 dB respectively. Results are listed in table 7.

6. SHUT-DOWN, SHOT-DOWN MODES

Two modes of partial down times are expected when operating with a 4-tower array - the shut-down mode in which two antennas are shut down for maintenance, and the shot-down mode in which one tower has been shot down or has not yet been erected. In the latter case the third opposing antenna is expected to be shut down to preserve the phase center of radiation. While not utilized for radiation, the inoperative antenna nevertheless is in the induction field of the other two antennas. To determine the voltage and currents in the inoperative tower, the situation shown in figure 33 was set up. As illustrated, the two opposing towers east and west were transmitting, while measurements were made in the north tower. Voltage measurements were made at the end of each radial; these voltages, designated E1 through E9, were approximately equal to voltage E_a, the input to the east and west antennas. Current measurements were made of radial currents I1 through I4; these indicated attenuated currents down 37 to 38 dB from the antenna current I_a flowing into the east and west antennas.

TABLE 7. HARMONIC RADIATION EFFICIENCY

Config. No.	Height (Ft.)	No. of Towers	Radiation Fundamental	Resistance 2nd Harmonic (Ohms)	Resistance 3rd Harmonic (Ohms)
22	4	4	0.58	2.66	12.94
23	4	4	0.70	3.60	8.26

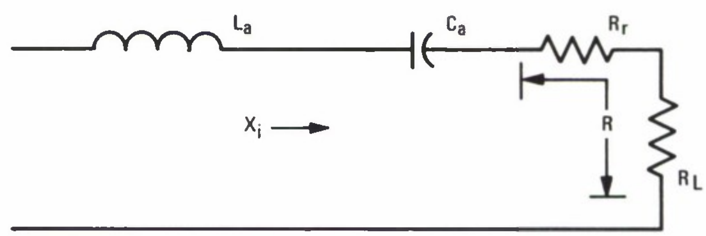
SECTION V

DISCUSSION AND CONCLUSIONS

1. GENERAL

This antenna study and model testing program has as its objective the selection of one or more antenna arrays composed of two or more standard tower antennas to achieve increased radiation and power transmission. It has long been recognized that antenna design and comparison for the Loran pulse system must not only consider the efficiency based on cw or steady state measurements; dealing with a narrow pulse system, the antenna must also be analyzed on a transient basis involving its bandwidth. The analysis of "short" antennas for Loran based on simple series RLC circuit theory has therefore been made in terms of bandwidth and efficiency. These will be briefly reviewed here.

The antenna will be represented by its equivalent series circuit shown below:



2. INTRINSIC BANDWIDTH

For the equivalent antenna circuit shown above, the bandwidth is:

$$\Delta f = \frac{2R}{-\frac{X_i}{f_o} + \frac{dX_i}{df(f_o)}} = 2\pi f_o^2 C_a R \qquad \text{(references 2, 5 and appendix V)} \qquad (9)$$

and the radiation efficiency of the antenna is defined as:

$$\eta_A = \frac{R_r}{R_r + R_L} \tag{10}$$

where

R_r = radiation resistance

R_L = total heat loss resistance of antenna system

If R in equation (9) is defined as the radiation resistance Rr then Δf equals the intrinsic or 100% efficiency bandwidth:

$$\Delta f = 2 \pi f_o^2 C_a R_r \tag{11}$$

The bandwidth-efficiency product however is defined as:

$$f = \eta_A \Delta f = \eta_A 2 \pi f_o^2 C_a R_r \tag{12}$$

Equation (12) has generally been employed to analyze the entire antenna system including the ground plane and transmitter interface, since the heat loss resistance is composed of ground plane resistance, transmitter coupler loss resistance and antenna loss resistance. In the program performed here, these losses cannot be directly scaled to actual full-size antenna values for various reasons. As previously noted, the top loading and radial feed wires are not scaled correctly, nor was it practical to duplicate the actual transmitter tuning coil. The ground plane resistance while satisfactory, may not be a duplicate of the actual installation.

In view of the foregoing, antenna arrays will be analyzed primarily in terms of the intrinisic or 100% efficiency bandwidth Δf and will be discussed separately.

It has been shown (reference 4) that for Loran, the sampling point power is directly proportional to the efficiency bandwidth product and in view of the above discussion, to the intrinsic bandwidth. Computer network simulation of the Sperry SCR transmitter indicates that for a fixed transmitter configuration and variable antenna coupling arrangement, the available reactive energy in the antenna at the pulse peak or sampling point ($I_a^2 X_{C_a}$) is a constant. Thus if:

$$I_a^2 X_{C_a} = K = \frac{I_a^2}{2\pi f_o C_a} \tag{13}$$

$$I_a^2 = K 2\pi f_o C_a \tag{14}$$

and since power transmitted is:

$$P = I_a^2 R_r$$

then:

$$P = K 2\pi f_o C_a R_r \tag{15}$$

It is thus evident that maximizing the intrinsic bandwidth (or the antenna capacitance and radiation resistance) will result in the maximum transmitted power.

The objective of the study therefore was primarily concerned with the measurement and optimization of C_a and R_r. These quantities as well as the intrinsic bandwidth have been tabulated in table 5 and can now be studied.

To enable a better comparison with the standard 4-foot tower antenna employed with the AN/TRN-39 (configuration 3) all values of Δf have also been normalized with respect to that antenna.

3. OPTIMUM CONFIGURATION

Examination of the normalized values of Δf clearly indicates the superiority of configurations 15 and 29 for 2-tower and 4-tower arrays, respectively, as illustrated in figures 34 and 35. Both these configurations employ double tower insulation, that is the tower top is insulated from the top hat and from the ground plane. Both these configurations also require physical separation between each component antenna of the array. The intrinsic bandwidth and its normalized value for each configuration are represented below:

CONFIGURATION	Δf*	Δf RELATIVE TO STANDARD ANTENNA
2-antenna array (#15)	57.9	1.51
4-antenna array (#29)	126.6	3.31

*Divide by 100 for full scale antenna.

The superiority of these arrays is of course due to maximizing C_a and R_r. The conditions under which these terms have been found optimum are:

- Radiation resistance increases by insulating the tower structure from both top hat and ground base. This held true for a single slant-fed antenna or an array of 2 or 4 antennas. It is believed that by permitting the central tower structure to be an integral part of the top hat, a downward current is allowed to flow which causes partial cancellation of the current injected into the upward slanted-feed radial.

- Radition resistance increases by adequate separation of the component antennas. It was found that the arrangement shown in figure 2, which confined the four antennas into the guy anchor circle of the USCG 625-ft antenna, prevented the most efficient radiation of each component antenna, inasmuch as it did not allow for field fringing at the umbrella ends facing each other. Thus the 4-antenna array shown in figure 2 did not provide as much radiation resistance as a single antenna. The proximity problem did not exist in the 2-antenna array where two diagonally opposite antennas were used.

- Antenna capacitance has been found optimum for a grounded tower operation (configuration 4) inasmuch as this connection extends the ground plane up to the tower top. This connection however is not optimum for radiation resistance as discussed above. Insulating the tower at both ends (configuration 10) exacts a penalty in antenna capacitance, but maximizes Δf. Therefore the insulated tower connection is recommended.

- Separation of component antennas is required to achieve the correct addition of individual antenna capacitances, for the same reason as noted above for the optimization of radiation resistance. The total top hat or umbrella area including allowance for field fringing for the array must equal the umbrella area of a single antenna multiplied by the number of these employed in the array. For the 2-antenna array which employs any 2 diagonally opposite antennas in figure 2, no additional separation was required. For the 4-antenna array shown in figure 2, an additional 2-foot

separation between each antenna and its feed point was required. The total diameter of this array is consequently increased from 18 to 22 feet (1800 to 2200 feet full scale).

In the recommended configuration, the antenna tower structure is isolated from ground and thus vulnerable to static charging. To prevent this buildup of charges a bleeder resistance on the order of 1000 ohms must be connected across the base of the antenna.

At the outset of the project it was expected to realize twice as much bandwidth for a 2-antenna array and four times as much for a 4-antenna array compared to a single standard 400-foot full scale antenna. These multipliers would permit an increase in radiated power of 2 and 4 times respectively. Analyzing the data presented, it is concluded that an approximate shortfall of 10% each in radiation resistance and in antenna capacitance have caused a 20% bandwidth or power reduction in the models studied to this point.

4. INPUT REACTANCE

Another consideration which must be carefully adhered to in the selection of the optimum antenna is the input reactance. For efficient energy transfer, the reactive components of the input impedance must be negative, that is the capacitive term must dominate. In the customary series resonant antenna circuit, there is optimum power transfer when all capactive energy is utilized in charging the antenna capacitance and when the circuit resonates at 100 kHz. This series resonance is effected by augmenting the antenna inductance (L_a) with a driving inductance (L_T) in the transmitter. A portion of this driving inductance is made variable to permit fine tuning of the antenna, allowing for slight variation in antennas and antenna installation.

When remoting the transmitter, the driving inductance also includes the distributed inductance of the driving coaxial cable. Sperry utilizes a special cable for the AN/TRN-39 with an equivalent 45 microhenry inductance for a 600-foot length. Allowance must consequently also be made for this inductance.

In summary, the antenna input reactance must be sufficiently negative to permit inductive tuning of the antenna, making allowance for the drive cable inductance and antenna tolerances.

In analyzing and testing the antenna configurations it becomes apparent that for slant-fed configurations, the antenna inductance (and resistance) is primarily a function of the slant-feed wire which conducts the current to the top hat. In lieu of utilizing the measured inductance values, which have been shown to be incorrect because of the impracticality of exact wire scaling, inductance calculations have been performed for the actual slant-feed cable. These calculations were performed using the self-inductance formulas by Grover (reference 6) for various lengths of feed wire. Since the antennas are essentially operating in parallel in the 2- or 4- tower arrays, inductance values are divided either by 2 or 4.

It is of interest to examine the probable output configuration for tuning and matching the antenna array, as shown in figure 36. Listed in table 8 for the two optimum configurations is the total inductance required for resonance at 100 kHz, the cable inductance and the transmitter tuning inductance, the latter two reduced by the square of the matching transformer ratio (see lines 1 and 2 in the table).

It is apparent that the antenna in the two models, in combination with the cable and tolerancing inductance, exceeds the required inductance and that alternative feed configurations or connections need to be examined. One possible solution here is to parallel the slant-feed wire with one of equal diameter spaced 2 to 3 feet from it. The antenna inductance L_a reduces then to 139 and 89 microhenries, respectively, as shown in lines 3 and 4 in the table.

Another possible approach is the modification of the top hat configuration to one with shorter top loading elements. The relationship between radial length, capacitance and radiation resistance has been documented by Devaney et al (reference 1). Applying these relations to the 4-foot top loaded antenna it can be shown that a reduction in top loading length from 4 to 3 feet should reduce antenna capacitance by 25% and reduce bandwidth by 7.5%. The bandwidth will then suffer only a slight decrease, while the 25% decrease in capacitance increases the required total inductance to 299 and 132 microhenries respectively, comfortably larger than the calculated inductances (see table 8, lines 5 and 6, and Section VI).

5. INPUT RESISTANCE

It has previously been noted that the proper scaling of the heat loss resistance was neither practical nor possible. Various measurements and testing have confirmed

that the bulk of the antenna loss resistance is that of the slant-feed wire, as was the case for the antenna inductance. In lieu of model measurement, the approach followed was to measure and calculate the AC resistance at 100 kHz of the type of wire actually employed with the full scale antenna.

At the present time, Times Wire and Cable of Wallingford, Connecticut is producing under subcontract the top loading wire for the antenna to be utilized with the AN/TRN-39. The wire is manufactured by placing a double layer of braiding over 0.312 diameter phyllystran cable. The cable resistance at 100 kHz has been measured at Times Wire and Cable and reported to be 2.5 ohms per 1000 feet.

The expected cable loss resistance for 4 parallel antenna feed wires 763 feet long is therefore 0.48 ohms and for two parallel feed wires 600 feet long it is 0.75 ohms. The values are well within the total loss resistance tolerances specified for the AN/TRN-39 (4.8 ohms maximum) or those measured with AN/TRN-21-A equipment (normally 4 ohms). The total loss resistance, of course, includes the ground plane resistance which contributes the major part of the losses.

6. PARTIAL OPERATION (SHUT-DOWN, SHOT-DOWN MODES)

During partial operation, two of the antennas in the 4-antenna array are inoperative either due to maintenance, partial erection of the array, or casualty. The following conclusions regarding continuing transmission during such a phase are presented.

- When diagonally opposite antennas are selected as the active units there will be no shift in the electrical phase center of the transmitted signal
- The omnidirectional character of the transmission will be maintained, as verified by directional field intensity measurements.
- Tuning lends itself to parallel tuning coil arrangements or transformer tap changes. The antenna capacitance is halved when only two antennas are driven and the required tuning inductance then must be doubled.
- Any part of the non-active antennas, being in the near field of the active units, will charge up to a voltage high enough to be dangerous to personnel. It there is therefore recommended that no maintenance activities involving personnel be performed during signal transmission.

- The tests performed on the partial configuration indicate that the preferred method of operating with inactive towers is to float the antenna (except for a tower bleeder resistance), that is, not to ground either the tower, radials or feed wire. If this precaution is not taken, circulating currents will cause a significant reduction in transmitted power.

7. DIRECTIONAL EFFECTS

The top loaded monopole antenna has previously been shown by investigation and actual use to be omnidirectional. This characteristic is not modified by paralleling individual towers to form multitower arrays, primarily because dimensionally each array is still much smaller than a 100 kHz wavelength. The circular tests performed during this program on most of the antenna configurations have shown variation of only 1 to 2 dB and these were found to be more a function of the actual spot where a measurement was performed than the configuration employed.

8. ANTENNA VOLTAGES

In each antenna configuration, high voltages will appear at various points on the antenna requiring that the insulating portion withstand these potentials. Of specific interest in the recommended antenna configurations are the potentials at each top hat since the tower structure must be insulated and the input voltage at the slant-feed radial is driven from a coaxial cable.

Examining the circuit in figure 36, and considering that the antenna inductance is primarily the inductance of the slant-feed wire, it can be concluded that the potential between A and ground is the top hat voltage E_{TH}, which exists across both insulating ends of the tower structure. Voltage E_{TH} is simply the product $I_a X_{C_a}$ where I_a is individual antenna current and X_{C_a} is the capacitive reactance of each single antenna. Table 8 shows the top hat potentials expected for each of the configurations listed in that table.

The slant-feed potential E_i is the product $I_a X_i$ where X_i is the parallel input reactance of the antenna array and I_a is the total input current. Since X_i is small, the antenna being self resonant near 100 kHz, the expected input voltage is relatively low. This simplifies insulation requirements for the transmitted output circuitry especially for the 600-foot transmission line. The values for E_i are shown in table 8.

TABLE 8. ANTENNA TUNING

Configuration	Calculated Antenna Current* (Amperes, peak)	Antenna Capacitance (pf)	Required Inductance (micro-Henry)	Calculated Antenna Inductance (micro-Henry)	Cable Inductance (micro-Henry)	Tuning Inductance (micro-Henry)	Calculated Input Voltage E_i (volts, peak)	Calculated Top Hat Voltage E_{TH} (volts, peak)
1. 2-Antenna (15)	380	10,600	239	210	23	10	-	57.4K
2. 4-Antenna (29)	570	24,000	106	114	12	5	-	38.0K
3. 2-Antenna (15) Parallel Feed	380	10,600	239	139	23	10	24.3K	57.4K
4. 4-Antenna (29) Parallel Feed	570	24,000	106	89	12	5	6.3K	38.0K
5. 2-Antenna (15) Reduced Top Loading (Estimated)	328	7,950	299	210	23	10	23.0K	65.9K
6. 4-Antenna (29) Reduced Top Loading (Estimated)	493	18,000	132	114	12	5	8.8K	43.8K

- - - - - - -

*When driven by Loran D Transmitter AN/TRN-39

9. GROUND PLANE

Consideration has been given to the relative merits of establishing a single central ground plane for the entire antenna array, versus single ground planes associated with each antenna. Because the low-Q wide-band antenna does not require an optimum ground system the investigation has been largely governed by:

- Keeping the present electrical characteristic, that is, a ground loss resistance of the order of a few ohms.
- Simplicity and rapid installation techniques.
- Material cost and weight factors.

For the present Loran-D antenna the ground system is formed with aluminum ground radials connected to a central ground point. Continuing with this approach and ruling out the crossing of ground radials, the choice is between a radial installation with the central feed point as the center, or the prior technique with each tower base as the radial center. It was found that for the same linear footage, an installation from the central feed point would provide insufficient coverage below the outer top loading elements of each tower and would provide coverage in the area of the cusps where it is not required.

The recommended ground plane configuration, shown in figures 37 and 38 therefore contains four individual ground planes, each associated with use of the component antennas and attached to the antenna base plate. A ground wire then connects each base plate to the matching unit.

The system proposed is concentrated under each top hat where maximum top-hat-to-ground capacitance is achieved, and it further makes use of all the simplifying techniques developed for the Loran-D system. Among these is the ability to supply the ground wires precut in one or two sizes and packaged on reels.

SECTION VI

RECOMMENDATION

The tests of the model 150-foot towers, even with a 4-tower array, show an intrinsic bandwidth, Δf, of less than one-fifth that of a single 400-foot tower. The use of 150-foot towers, despite the ease of erection, should not be given further consideration.

The tests so far conducted with the model 400-foot towers have shown that it is necessary to utilize a 2200-foot diameter circle for the antenna array, providing the maximum Δf, or power output, with the top loading configuration described. Reducing the active length of the top loading elements should be explored by further studies to determine if the circle can be reduced in area while maintaining a high Δf. The reduction in top loading length will also raise the antenna resonant frequency, simplifying antenna tuning and permitting the use of a single-feed conductor per antenna.

The investigation of non-uniform top loading arrays also seems indicated. The measured non-directional characteristic of the 2-tower array suggests that the top loading elements running away from the center of the array may be lengthened to increase Δf. Non-uniform top loading arrangements had not originally been considered due to an apprehension of a non-uniform radiation pattern.

REFERENCES

1. Low-Frequency Top-Loaded Antennas - T. E. Devaney, R. F. Hull, W. E. Gustafson, 1966, U.S. Navy Electronics Laboratory, San Diego, Cal. NEL Report 1381

2. Analysis of the Characteristics of Electrically Short Top-Loaded Antennas of the Umbrella Type - Harry F. Hartley, Westinghouse Electric Corporation, Baltimore, Maryland

3. Loran D 400-Ft. Antenna Modification and Configuration Study, Volume 1, Sperry Gyroscope Division, Sperry Rand Corporation, Great Neck, N.Y., March 1972

4. Project W-324, Test and Evaluation of Scale-Model Antennas - Final Report (not in general distribution), U.S. Coast Guard, Electronics Engineering Center, Wildwood, N.Y., 13 Sept. 1968

5. The Characteristics of Electrically Short Umbrella Top-Loaded Antennas - A. F. Gangi and G. R. Dunn, IEEE Transactions in Antennas and Propagation, Volume AP 13, No. 6, November 1965

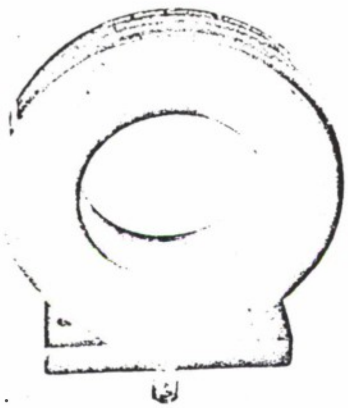
6. Inductance Calculations - Frederick W. Grover, V. Van Nostrand, New York, 1946

APPENDIX I

WIDE-BAND CURRENT TRANSFORMER SPECIFICATION

WIDE BAND CURRENT TRANSFORMER

Precision PULSE CURRENT TRANSFORMER



Model 110

This current transformer is flat from 1 Hz to 35 MHz (3 dB points). It is useful for audio, video, rf and pulse measurements. Current being measured can be in a conductor at low or very high voltage, or a beam of charged particles.

• SPECIFICATIONS

1. Output Voltage/Ampere - 0.1 (+1%, -0%, initial pulse response).
2. Rise Time - 20 nanoseconds for a step-function current pulse.
3. Droop - 0.5% per millisecond for top of a square wave or pulse.
4. Pulse $I\tau$ - 0.6 ampere second max. (small bias current in secondary needed for values approaching this max.).
5. Frequency Response - 1 Hz to 35 MHz at 3 dB points.
6. Sine Wave I/f - 2.5 amps peak per Hz.
7. Current - 5,000 amps peak, 50 amps rms maximum.
8. Insertion Resistance - 0.0002 ohm.
9. Voltage between Center Conductor and Case - 30 kV flashover in air for 3/4" diam bare center conductor.
10. Capacity Added to Circuit - 4 pF in oil, 2 pF in air, for typical installation.
11. Output Connection - BNC receptacle.
12. Cable - 50 ohm cable such as RG-58C/U.
13. Cable Termination - typical oscilloscope input (e.g., 1 megohm and 20 pF in parallel).
14. Overall Dimensions - 4" OD x 1" thick, 2" ID.

PEARSON ELECTRONICS, INC

APPENDIX II

FIELD INTENSITY METER AND LOOP ANTENNA FACTORS

SPERRY [illegible] DIVISION
CENTRAL INSTRUMENT SERVICES - DEPT. 4680

Test Instr.: Noise/Field Int. Meter SIDAC No. 029244

Mfr.: Empire Devices Model NF-105 S/N: 1308 I-C/R Spec/Proc. #

Cal. By: Nat'l Cal Services Date: 3/26/75 Approved: [illegible] Date: 3/28/75

SP/PROC PAR. #	FUNCTION	~~NOMINAL~~	LOWER LIMIT	~~MEASURED~~	UPPER LIMIT	~~[illegible]~~	OUT OF TOL.	REMARKS
503253	INPUT ATTENUATOR	SUBJECT		STANDARD		CORRECTION		
		(db)		(db)		(db)		
		80.0		80.0		—		
		60.0		60.1		-0.1		
		40.0		40.1		-0.1		
		20.0		20.2		-0.2		
		0.0		19.8		—		
	SUBTRACT 10db	= 10.0db						
	SIG. INPUT TRACKING							
	(METER)	SUBJECT		STANDARD		CORRECTION		
		(db)		(db)		(db)		
		20.0		20		—		
		18.2		18		-0.2		
		16.2		16		-0.2		
		14.3		14		-0.3		
		12.3		12		-0.3		
		10.0		10		—		
		7.9		8		+0.1		
		5.8		6		+0.2		
		3.7		4		+0.3		
		1.7		2		+0.3		
		<0.0		0		+		
503254	TUNING HEAD - T-A/NF105			SIDAC# 003112				
	BAND	SET FREQ		ATTEN.		IF GAIN		
	5.2 - 12.7 MHZ	10.0		20.0db		76.0db		
	12.7 - 30 MHZ	20.0		20.0db		76.2db		
	"	30.0		20.0db		76.3db		
	IF GAIN: 100,000 MICROVOLTS AT 80.0 db.							

SCC FORM # 108-A DATA SHEET SHEET 1 OF 1

INCAL
SERVICE
CORPORATION

73 SOUTHFIELD AVENUE
STAMFORD CONN 06902
PHONE (203) 327-9668

ANTENNA "FACTOR" FOR LOOP ANT LP-105

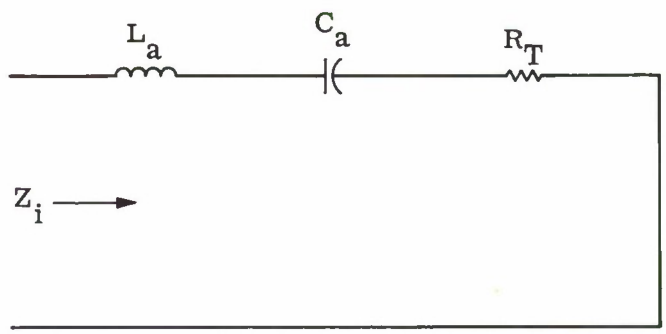
FREQ	DB	FREQUENCY	DB
150 kc	43.0	2.4 mc	28.5
175 kc	41.8	2.7 mc	28.0
200 kc	40.7	3.0 mc	27.5
225 kc	40.2	3.4 mc	27.0
250 kc	38.6	3.7 mc	26.5
275 kc	38.5	4.0 mc	25.5
300 kc	38.0	4.4 mc	24.5
325 kc	38.0	4.7 mc	24.0
360 kc	37.5	5.2 mc	23.5
400 kc	38.5	6.0 mc	25.0
450 kc	38.0	7.0 mc	24.0
500 kc	37.5	8.0 mc	23.0
560 kc	36.5	9.0 mc	22.5
620 kc	36.0	10.0 mc	21.5
700 kc	35.0	11.0 mc	20.5
760 kc	34.0	12.0 mc	20.3
820 kc	33.0		
870 kc	32.0		
900 kc	35.5	12.7 mc	21.5
1000 kc	34.5	15.0 mc	20.5
1.1 mc	33.5	29.0 mc	20.0
1.3 mc	32.0	21.0 mc	19.5
1.5 mc	31.0	24.0 mc	19.0
1.7 mc	29.0	27.0 mc	18.4
1.9 mc	28.0	30.0 mc	18.0
2.1 mc	27.5		

For substitution measurements add 20 db to the above factors.

Warranteed Instrument Calibration, Repair, & Renovation.

APPENDIX III

DERIVATION OF ANTENNA CAPACITANCE AND INDUCTANCE



Equivalent circuit for antenna input impedance

Let reactive part of $Z_i = X_i$

Then $$X_i = X_{L_a} - X_{C_a} \quad (1)$$

$$X_i = 2\pi f_{L_a} - \frac{1}{2\pi f \ C_a} \quad (2)$$

Differentiating with respect to f

$$\frac{dX_i}{dF} = 2\pi L_a + \frac{1}{2\pi f^2 \ C_a} \quad (3)$$

and $$f \left[\frac{dX_i}{df}\right] = 2\pi \ fL_a + \frac{1}{2\pi \ f \ C_a} \quad (4)$$

Subtracting (4) from (2)

$$X_i - f \left[\frac{dX_i}{df}\right] = \frac{-2}{2\pi \ f \ C_a} = -2 \ X_{C_a} \quad (5)$$

$$X_{C_a} = \frac{f \ \frac{dX_i}{df} - X_i}{2} \quad (6)$$

and $$X_{L_a} = X_i + X_{C_a} \quad (7)$$

APPENDIX IV

POWER FIELD FORMULA

Assumptions:

- Far field
- No losses
- Flat, perfectly conducting earth
- E-field measured at low elevation angle $\theta_e = E_M$
- Cos θ_e field dependence
- Z_o = free space impedance = 377Ω
- Measured E_M means $E(\theta_e) = \begin{cases} E_M \cos\theta_e, & \theta_e \geq 0 \\ 0, & \theta_e < 0 \end{cases}$

Total power radiated at transmitter site, measured by E-field at distance d from transmitter:

$$P\ (\text{watts}) = \int_0^{\pi/2} \frac{(E_M \cos\theta_e)^2}{Z_o} \underbrace{2\pi d^2 \cos\theta_e\, d\theta_e}_{\text{area element}}$$

$$= \frac{E_M^2}{Z_o} 2\pi d^2 \int_0^{\pi/2} \cos^3\theta_e\, d\theta_e = \frac{E_M^2}{Z_o} \frac{4}{3}\pi d^2$$

$$P = \left[\frac{E_M}{9.487}\right]^2 \cdot d^2\ (\text{watts})\ \text{or} \left[\frac{E_M}{300.0}\right]^2 \cdot d^2 (\text{kW}) \quad \begin{cases} E \text{ in volts/length unit} \\ d \text{ in same length unit} \end{cases}$$

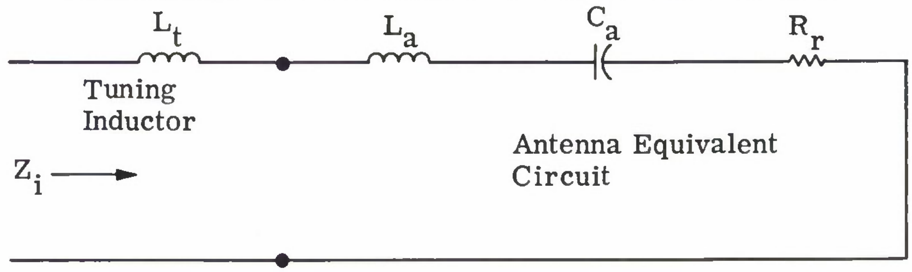
or $$P_{kW} = \left[\frac{E_M}{186.4}\right]^2 \cdot d^2 = I^2 R_r$$

$$R_r = \left[\frac{E_M\, d}{186.4\, I}\right]^2 \cdot 1000$$

$\begin{cases} E_M \text{ in millivolts/meter} \\ d \text{ in miles} \end{cases}$

APPENDIX V

DERIVATION OF INTRINSIC ANTENNA BANDWIDTH



Equivalent Antenna Circuit

Let the bandwidth of the single tuned circuit shown $= \Delta f$

$$\Delta f = \frac{f_o}{Q} = \frac{2 R_r}{\frac{dX}{df}(f_o)} \qquad (1)$$

(see reference 2)

Where f_o = resonant frequency

Δf = 3 db amplitude bandwidth

$\frac{dX}{df\,(f_o)}$ = reactance slope at f_o

R_r = Radiator resistance

Also $Z_i = R_i + jX_i$

$$X = X_{L_t} + X_{L_a} - X_{C_a} \qquad (2)$$

$$X_i = X_{L_a} - X_{C_a}$$

Where X_{L_t} = Reactance of tuning inductor

X_{L_a} = Reactance of antenna inductance

X_{C_a} = Reactance of antenna capacity

Differentiating $\frac{dX}{df} = 2\pi L_t + \frac{dX_i}{df}$ (3)

At resonance f_o $|X_i| = |X_{L_t}|$

and $\frac{dX}{df\,(f_o)} = \frac{X_i}{f_o} + \frac{dX_i}{df\,(f_o)}$ (4)

Substituting equation (4) into (1)

$$\Delta f = \frac{2 R_r}{\frac{dX}{df(f_o)}} = \frac{2 R_r}{\frac{dX_i}{df(f_o)} - \frac{X_i}{f_o}} \tag{5}$$

the intrinsic bandwidth

$$\text{Since} \quad X_i = X_{L_a} - X_{C_a} = 2\pi f_{L_a} - \frac{1}{2\pi f_o C_a} = \frac{(2\pi f_o)^2 C_a L_a - 1}{2 f_o C_a} \tag{6}$$

$$\frac{dX_i}{df(f_o)} = 2\pi L_a + \frac{1}{2\pi C_a f_o^2}$$

$$= \frac{(2\pi f_o)^2 L_a C_a + 1}{2\pi C_a f_o^2} \tag{7}$$

Substituting (6) and (7) into (5)

$$\Delta f = \frac{2 R_r}{\frac{(2\pi (f_o)^2 L_a C_a + 1}{2\pi C_a f_o^2} - \frac{1}{f_o} \frac{(2\pi f_o)^2 - 1}{2\pi f_o C_a}}$$

$$\Delta f = 2\pi f_o^2 R_r C_a \tag{8}$$

the intrinsic bandwidth

APPENDIX VI

FCC AUTHORIZATION

FCC Form 450-D
June 1966

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION
EXPERIMENTAL
SPECIAL TEMPORARY AUTHORIZATION

EXPERIMENTAL (DEVELOPMENTAL)
(Nature of service)

K C 2 X E J
(Call sign)

EXPERIMENTAL XD FX
(Class of station)

S-6591-ED-74-1
(File number)

NAME SPERRY RAND CORPORATION SPERRY GYROSCOPE DIVISION

Lake Success (Nassau) New York - Lat. 40 45 18 N; Long. 73 42 35 W.
(Location of station)

(Location of authorized remote control point)

Special Temporary Authority is hereby granted to operate the radio transmitting apparatus described below:

Frequency	Emission Designator	Authorized Power (Watts)	Special Provisions
19.0-19.98 MHz	A0	1.0	
20.03-21.00 MHz	A0	1.0	
21.45-21.50 MHz	A0	1.0	
29.70-29.89 MHz	A0	1.0	
30.56-31.50 MHz	A0	1.0	

This special temporary authorization is granted upon the express condition that it may be terminated by the Commission at any time without advance notice or hearing if in its discretion the need for such action arises. Nothing contained herein shall be construed as a finding by the Commission that the authority herein granted is or will be in the public interest beyond the express terms hereof.

This special temporary authorization shall not vest in the grantee any right to operate the station nor any right in the use of the frequencies designated in the authorization beyond the term hereof, nor in any other manner than authorized herein. Neither the authorization nor the right granted hereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934. This authorization is subject to the right of use of control by the Government of the United States conferred by Section 606 of the Communications Act of 1934.

This authorization effective August 7, 1974 and

will expire 3:00 A.M. EST February 7, 1975.

FEDERAL COMMUNICATIONS COMMISSION

Ben F. Waple
Secretary.

F.C.C. - WASHINGTON, D. C.

FCC Form 450-D
June 1966

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION

EXPERIMENTAL (DEVELOPMENTAL)
(Nature of service)

EXPERIMENTAL
SPECIAL TEMPORARY AUTHORIZATION

K C 2 X F L
(Call sign)

EXPERIMENTAL XD FX
(Class of station)

S-6592-ED-74-2
(File number)

NAME SPERRY RAND CORPORATION

Islip (Suffolk) New York - Lat. 40 47 52 N; Long. 73 06 29 W.
(Location of station)

(Location of authorized remote control point)

Special Temporary Authority is hereby granted to operate the radio transmitting apparatus described below:

Frequency	Emission Designator	Authorized Power (Watts)	Special Provisions
19.0-19.98 MHz	AO	1.0	
20.03-21.00 MHz	AO	1.0	
21.45-21.50 MHz	AO	1.0	
29.70-29.89 MHz	AO	1.0	
29.91-29.97 MHz	AO	1.0	
30.56-31.50 MHz	AO	1.0	

Special Condition:

(1) The station identification requirements of Section 5.152 of the Commission's Rules are waived.

This special temporary authorization is granted upon the express condition that it may be terminated by the Commission at any time without advance notice or hearing if in its discretion the need for such action arises. Nothing contained herein shall be construed as a finding by the Commission that the authority herein granted is or will be in the public interest beyond the express terms hereof.

This special temporary authorization shall not vest in the grantee any right to operate the station nor any right in the use of the frequencies designated in the authorization beyond the term hereof, nor in any other manner than authorized herein. Neither the authorization nor the right granted hereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934. This authorization is subject to the right of use of control by the Government of the United States conferred by Section 606 of the Communications Act of 1934.

This authorization effective April 2, 1975 and

will expire 3:00 A.M. EST September 2, 1975.

FEDERAL COMMUNICATIONS COMMISSION

Ben F. Waple
Secretary.

F.C.C. - WASHINGTON, D. C.

FCC Form 450-B
September 1972

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION
EXPERIMENTAL
RADIO STATION CONSTRUCTION PERMIT
AND
LICENSE

EXPERIMENTAL (DEVELOPMENTAL) (Nature of service)

K C 2 X F J (Call sign)

EXPERIMENTAL XD FX (Class of station)

6591-ED-PL-74 (File number)

NAME SPERRY RAND CORPORATION, SPERRY GYROSCOPE DIVISION

Lake Success (Nassau) New York - Lat. 40 45 18 N; Long. 73 42 35 W.
(Location of station)

(Location of authorized remote control point)

Subject to the provisions of the Communications Act of 1934, subsequent acts, and treaties, and all regulations heretofore or hereafter made by this Commission, and further subject to the conditions and requirements set forth in this license, the licensee hereof is hereby authorized to use and operate the radio transmitting facilities hereinafter described for radio communication.

Frequency	Emission Designator	Authorized Power (Watts)	Special Provisions
9.5 - 9.99 MHz	AO	1	
10.010 - 10.5 MHz	AO	1	

Equipment: (1) Experimental

Frequency Tolerance: .005%

Hours of Operation: Daytime only

Operation: In accordance with Section 5.252(a) of the Commission's Rules.

The above frequencies are assigned on a temporary basis only and are subject to change at any time without hearing.

This authorization is granted subject to the condition that no harmful interference is caused to any other station or service and may be cancelled at any time without hearing if, in the judgment of the Commission, such action should be necessary.

This license is issued on the licensee's representation that the statements contained in licensee's application are true and that the undertakings therein contained, so far as they are consistent herewith, will be carried out in good faith. The licensee shall, during the term of this license, render such service as will serve public interest, convenience, or necessity to the full extent of the privileges herein conferred.

This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term hereof, nor in any other manner than authorized herein. Neither the license nor the right granted hereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934. This license is subject to the right of use or control by the Government of the United States conferred by Section 606 of the Communications Act of 1934.

FEDERAL COMMUNICATIONS COMMISSION

This authorization effective May 16, 1974 and
will expire 3:00 A.M. EST September 1, 1976

FEDERAL COMMUNICATIONS COMMISSION.

Secretary.

F.C.C. - WASHINGTON, D. C.

1. Upon completion of the station, in accordance with the terms of this permit, the grantee shall, on the forms and in the manner prescribed from time to time by the Commission, make it appear to the satisfaction of the Commission that all the terms, conditions, and obligations set forth in the application and in this permit have been fully met, and shall apply for a radio station license; upon such showing and application, and upon a finding by the Commission that since the granting of this permit no cause or circumstance has arisen which, in the judgment of the Commission makes the operation of the station against the public interest, a radio station license will be issued by the Commission for the operation of the station. The license will contain the conditions specified in Section 309 of the Communications Act of 1934, and such other terms and conditions as the Commission may prescribe.

2. This permit shall not vest in the grantee any right to operate the station, nor any right to a license authorizing the use of the particular frequency or the amount of power, or the time of operation herein specified. The Commission, in issuing this permit, reserves the right to assign whatever frequency, power, or time of operation it deems best calculated to serve public interest, convenience, or necessity. The terms of said license as to frequencies, power, emission, time of operation, and scope of communication are expressly made subject to the exercise of said reserved right.

3. Nothing contained herein shall be construed as a finding by the Commission on the question of marking or lighting of the antenna system should future conditions require. The permittee expressly agrees to install such marking or lighting as the Commission may hereafter require under the provisions of Section 303 (q) of the Communications Act of 1934.

4. This permit shall become automatically forfeited if the said station is not ready for operation within the time above specified, unless prior to the expiration of said permit the Commission shall have granted an extension of time. Upon proper showing, made to it by the grantee, prior to the expiration of such period, the Commission may grant an extension if it finds that the grantee was prevented from completing the construction of said station by causes not under grantee's control.

5. Neither this permit nor the right granted herein shall be assigned or otherwise transferred to any person, firm, company, or corporation without the written consent of the Commission.

F.C.C. - WASHINGTON, D. C.

APPENDIX VII

REPRODUCTION OF LOG 1 AND LOG 2 ORIGINAL DATA

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 1 SYSTEM SERIAL NUMBER ______

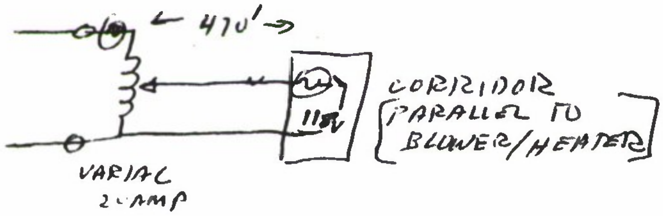
EQUIPMENT LOG FOR MULTIPLE TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

INSTALL GROUND PLANE TABLE AND AC CABLE IN EAST FIELD TEST SITE 10/25/74

ELECTRICAL HOOK UP OF AC POWER COMPLETED 10/28/74



REPLACE VARIAC - REWIRE FOR STEP-UP output 120 volt

CONNECT GROUND TO TABLE

VOLT DROP (500' TO FIELD INTENSITY METER CABLE) - 1.9V USING VARIAC.

WILL NOT USE VARIAC IN FUTURE

FIELD INTENSITY MEASUREMENTS UNCORRECTED 1500HRS

FREQ (MHZ) DIAL SETTING	E (db - 1uv level)
9.0	- 0.6
9.6	12
11.1	6

Move antenna on Table 10/29/74

setup TEST equipment

line drop 8 volts

Technician left early 10:30 AM

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10/30/74

$I_{in} = 0.025V \left(\frac{1}{.05\ V/a}\right) = 0.5$ amp p-p

$I_{in} = .177$ amp rms

V_{out}-(AMPLIFIER) $\approx$ 10 volt pp = 3.54 volt rms

Power out $\approx (.177)(3.54) = .63$ WATTS

Field Intensity Meter 200' East of antenna

$E = 35.3$ db above 1 µv ref

$= 35.3 \left[\frac{15.0}{15.3}\text{ meter correction}\right] + 36.3\text{db}\left(\text{Loop antenna correction}\right) + 0.2\text{db}$ 30' cable loss

$= 34.6 + 36.5$

$E = 71.1$ db

$E = 3.550$ mv/m

$$R_\Omega = \left[\frac{3.55 \times \frac{200}{5280}}{.177 \times 186.4}\right]^2$$

$R = .0166\ \Omega$ repair switchbox, near field, wrong calibration

Zin Measurements 8 Volt pp into Bridge

f	Xc	Rin	Xc(calc)	
9.930	$\frac{4000-2100}{9.93}$	.2	191 Ω	CONNECTOR GROUNDED AT BRIDGE
10.00	$\frac{4000-2400}{10.0}$	.35	160	GROUND AT BRIDGE
10.07	$\frac{4040-2470}{10.07}$	.38	152	

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Field Intensity E 300' East	10:30AM				

$E = 54.5 + 36.5 = 91$ db $= 35.5$ mv/m

$R_\Omega = \left[\frac{35.5}{.177} \quad \frac{300/5280}{186.4}\right]^2 = 3.7\Omega$ Recheck ok

OBSTRUCTION Within 10 fT of loop Antenna effects data

$f = 9.932$ MHz $I_{in} = .5$ amp pp
Reading 54 db with + without Table ground strips Taped to Table
CONNECT SPEACKER ARRANGEMENT - Excellent
Zin impedance, $E_{in} = 8$ volt pp in $f = 10.000$ MHz

$X_C = \frac{4000-2470}{10.00} = 153\,\Omega$ Ground AT Bridge shielded connector grounded at Bridge

$X_C = \frac{4000-2410}{10.00} = 159\,\Omega$ NO Ground ON CONNECTOR GROUND AT BRIDGE

$X_C = \frac{4000-2390}{10.00} = 161\,\Omega$ GROUND AT CONNECTOR CONNECTOR grounded AT BRIDGE

$X_C = 161\,\Omega = \frac{1}{2\pi f C}$

$C = \frac{1}{2\pi\, 10^7\, 161} = 989\,pf$

should be $X_C = 207\,\Omega$ ~~769 pf~~ STB.

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GROUND STRIPS PERMANENTLY FASTENED 11/5/74
TO GROUND PLANE TABLE (WATER PROOFING)

GROUND TIED WIRES SUPPORTS TO TABLE
TOP

RADIALS ~~were~~ WERE 3/4" TOO LONG,
FIXED RADIAL LENGTHS.

PUT LOOP ⊥ TO METER

f = 9.929 MHz

? I_{in} = .04 .05 amp P-P = .28 amp rms V_{in} ≈ 45 vpp

E distance East

36.51 + 14.5 db = 11.2 mv	300'	.057	Meter to side of loop	Rn = .15
36.5 + 45.6 = 12.6	300	.057	Meter behind loop	Rn = .19
36.5 + 41.3 = 7.94	250	.047 mi		Rn = .05
36.5 + 47.1 = 15.8	200	.039		Rn = .14

Reading WRONG

11/6/74

MUST GROUND CART WITH METER
ALL PREVIOUS FIELD INTENSITY DATA N.G.

I_{IN} = 25 mv-PP/50 mv/amp $\left(\frac{.707}{2}\right)$ = .177 amp rms

D FT.	E UNCORRECTED DB	+36.5 DB	E CORRECTED DB	MV/M	Rn Ω
350	48.5	+36.5	85.0	17.8	1.28
300	49.6	"	86.1	20.1	1.20
250	51.7	"	88.2	25.6	1.35
200	53.5	"	90.0	31.6	1.3
150	56.7	"	93.2	47.0	1.64
100	58.9	"	95.4	59.0	1.15
50	68.6	"	105.1	102.0	0.86

2.1db

5.4

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				11/6/74	

Z_{in} MEASUREMENTS

10 MHz $\frac{4000-2480}{10.0} = 152\,\Omega = X_c$

9.900 $\frac{4000-2500}{9.9} = 151.5\,\Omega$

9.500 $\frac{4000-2500}{9.5} = 157.9\,\Omega$

10.1 $\frac{4000-2680}{10.1} = 130.7 = ?$

10.5 $\frac{4000-2500}{10.5}$ 142.9 Ω

10.0 $\frac{4000-2500}{10.0} = 150.0\,\Omega$

I_{in} = 25 mv pp / 50 mv/amp $\left(\frac{.707}{2}\right)$ = 0.177 amp rms 11/7/74

f = 9.93 MHz

	Distance ft.	db uncor		E db cor	mv/m	$R\ \Omega$
8.8	50	68.3	+36.5 =	104.8 db :	102	0.86
	100	59.5		96.0	63.1	1.31
6.0	150	57.0		93.5	47.0	1.64
6.4	200	53.5		90.0	31.6	1.32
	250	51.8		88.3	26.0	1.39
4.8	300	50.6		87.1	22.6	1.50
	350	48.0		84.5	16.8	1.14
	400	48.7		85.2	18.3	1.77

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11/7/74

8 MHz USING DIFFERENT ZERO-BRIDGE SETTING

8 MHz $\frac{5000-3210}{8} = 223\Omega = X_C$ $R_{in} = 36\Omega$

8 MHz $\frac{3000-1850}{8} = 143\Omega = X_C$ R_{in} 33

8 MHz $\frac{4000-2160}{8} = 230 = X_C =$ R_{in} 33

freq	X_{in} Reading	X_C Ω	R_{in} Ω
8.0	2160	230	33
8.5	2210	211	38.2
9.0	2270	192	36
9.5	2380	171	41.2
10.0	2350	165	40.5
10.5	2490	143	44.5
11.0	2610	126	39.5
11.5	2730	110	47.5
12.0	3890	9.2	75.6 }?
12.5	2380	X_L +130	88.0 }?
Re-do			
12.5	2650	108	70.5
15.0	2840	77	67.8
16.0	3200	50	70.5

11/8/74
Radials - sagged
Noise spokes
moved because of
WIND - Tie Down
SPIKES with tape
& fixed radials

Measure off 205 feet circle

N 12
(1) W-9 6 3 E
S 5

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11/8/74

W –	48.0 +36.5	84.5 X–	
	45.5	82.0	
	47.5 ↑	84.0	
S	47.5	84.0	
	47.4	83.9	
	47.1	83.6	
E	46.9	83.4	
	46.7	83.2	
	45.9	82.4	
N	46.6	83.1	
	46.3	82.8	
	47.3	83.8	
W	46.1	82.6 ←	
	46.3 ↑	82.8	

AV = 83.3

MAX Δ $\frac{12}{14,100} \approx .1\%$ error

MAX Δ = $\frac{1.4}{83.3} = 1.7\%$ db

MAX Repeatability error

$\frac{84.5 - 82.8}{83.3} = 2\%$

83.3 db = 14.6 mv/m

$R_R = \left[\frac{14.6\left(\frac{205}{5280}\right)}{.085 \times 186.4}\right]^2 = 1.28\,\Omega$

$I_{in} = 1.2$ cm 10 mv/cm (PP) $\frac{1}{50\text{ mv/amp}}$ $\left(\frac{.707}{2}\right) = .085$ amp rms

11/12/74

205 EAST f = 9.929 MHz

I_{mv}	~~I amp rms~~	E_{db}	E_{db}	
30	~~.212~~	58.8	95.3	Δ 6.2 db
25	~~.177~~	56.8	93.3	
20	~~.141~~	55.0	91.5	Δ 5.8
15	~~.106~~	52.6	89.1	
10	~~.071~~	49.2	85.7	Δ 5.4
5	~~.035~~	43.8	80.3	

SAB

current ~~[illegible]~~ Transformer NOT Loaded FOR CALIBRATION – (USING SCOPE)

TRIED USING JOHNSON & CESCO REFLECTOMETER CONNECTED DIRECTLY TO ANTENNA – NG. – series Reson 11 MHz
parallel Reson – 23,33 MHz

USE XFMR, DISCONNECT JOHNSON MATCH BOX, PEAKED CURRENT @ 14.1 MHz (series reson) a @ 32.3 MHz parallel Reson.?

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@ 10 MHZ

$X_i = 2\pi f L - \frac{1}{2\pi f C} = \frac{(2\pi f)^2 LC - 1}{2\pi f C} = -165\,\Omega$ (should be $-201\,\Omega$)

$\frac{dX_i}{df} = 2\pi L + \frac{1}{2\pi f^2 C} = \frac{(2\pi f)^2 LC + 1}{2\pi f^2 C} = \frac{230 - 110}{11.5 - 8.0} = 34.3 \times 10^{-6}\ \Omega/Hz$

$(2\pi f)^2 LC = -165(2\pi f C) + 1$ (should be 36.0 after scaling)

$34.3 \times 10^{-6} = \frac{[-165(2\pi f C) + 1] + 1}{2\pi f^2 C}$

$34.3 \times 10^{-6}(2\pi f^2 C) = -165(2\pi f C) + 2$

$21{,}500 \times 10^{6}\, C = -10{,}360 \times 10^{6} C + 2$

$31{,}900 \times 10^{6} C = 2$

$C = 62.69 \times 10^{-12}$

62.69 pfd X100 (scaling)

$\therefore C_e = 5269\ pfd \Rightarrow 5600\ pfd$ should be

$X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi\, 10^{7}\, 5269 \times 10^{-12}}$

$X_c = \cancel{339}\ 302\,\Omega \Rightarrow 284$ should be

$-165 = 2\pi f L - \frac{1}{2\pi f C}$

$2\pi f L = 302 - 165 = \cancel{174}\ 137$

$L = 2.18 \times 10^{-6}$ X100 scaling

$L = 218\,\mu h \Rightarrow 122\,\mu h$ should be

$f_o = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} = \frac{1}{2\pi\sqrt{2.18 \times 10^{-6} \times 5269 \times 10^{-12}}}$

$f_o = 14.9 \times 10^{6}\ Hz = 14.9\ MHz$ resonance

149 ~~KHz~~ KHz resonance should be 185 KHZ

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Zin measurements 10 Vpp input 11/13/74

V_{in}	X_R	X_Ω	R
10 Vpp	2420	158 Ω	60
8	2590	141	63
6	2650	135	65
4	2600	140	62
2	2570	143	60

IMPEDANCE BRIDGE VOLTAGE INPUT

freq	X_R	X_Ω	R	
11	~~2400~~ 2400	145	78	using L-connector
10	~~2400~~ 2400	160	83	
9	~~2430~~ 2430	174	70	
10				
11	2400	145		No L-connector
10	2390	161		
9	2410	177		
Repeat 10	2390	161	88	No L-connector

Measure L-connector impedance - negligible

Using 150 pfd Mica Cap. across bridge 11/14/74

f = 9.95 MHz

Bridge input	
5 Vpp	2800
6 Vpp	2800
10	2800
20	2800
30	2800

$$X_C = 120.6 = \frac{1}{2\pi f C}$$

$$C = \frac{1}{(2\pi)\, 9.95 \times 10^6\, (120.6)} = 133 \text{ pfd}$$

11% From nominal

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11/14/74

10 Vpp input

f	Reading	R_i	X_i
8.5	2340	60	195
9.0	2420	65	176
9.5	2360	69	173
10.0	2390	66	161
10.5	2430	66	150
11.0	2430	60	143
11.5	2390	59	140

$X_i = -161$

$\frac{dX_i}{df} = 16.5 \times 10^{-6}$

$(2\pi f^2 C)\ 16.5 \times 10^{-6} = -161(2\pi f C) + 2$

$103.6 \times 10^{8} C = -101.1 \times 10^{8} C + 2$

$C = 97.7\ pfd$

$X_C = \frac{1}{2\pi f C} = -163$

$-161 = 2\pi f L - 163$

$L = 0.032\ \mu h$

11/15/74

Scope ground not connected to ground post-stale

TRIED VARIOUS GROUNDING ARRANGEMENTS 11/18/74

REMOVE BRAIDED GROUNDS FROM BRIDGE, OSCILLATOR,

CONNECT ground Table top Braid to Xin Lo of Bridge

measurement, connect Scope & Detector grounds

BIGGEST Effect on Bridge Null - Table Braid to Bridge Directly

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11-18-74

Measure standard Cap from instrument calibration Dept 100 pfd

$\frac{4000-2270}{9.98} = 173 = \frac{1}{2\pi f C} \Rightarrow C = 92\ pfd$

8% Low

f MHz	VBridge Input Vpp	Reading X	Xi Ω	Rin Ω
11	6	2550	132	22.5
10	6	2380	162	16.2
9	6	2340	184	14.0
11	10	2530	134	21.0
10	10	2410	159	15.5
9	10	2350	183	14.2

Reactance Bridge Volt Sens =

$\frac{162-159}{10-6} = .75\ \Omega/V$

was $5.75\ \Omega/V$

uncorrected for low Bridge readings

$X_i = -162 \Rightarrow 207$

$\frac{dX_i}{df} = \frac{183-132}{11-9} = 25.5 \Rightarrow 35$ data Ω/MHz

$25.5 \times 10^{-16}(2\pi f^2 C) = -162(2\pi f C) + 2$

$160 \times 10^8 C = -102 \times 10^8 C + 2$

$C = 76\ pfd \Rightarrow 56\ pfd$

$X_C = \frac{1}{2\pi f\ 76 \times 10^{-12}} = 210 \Rightarrow 284$

$-162 = 2\pi f L - 210$

$L = 0.76\ \mu h \Rightarrow 1.22$

correct Bridge readings 8.6%

$X_i = -149\ \Omega$

$\frac{dX_i}{df} = \frac{169-121}{11-9} = 24.0\ \Omega/MHz$

$24 \times 10^{-16}(2\pi f C) = -149(2\pi f C) + 2$

$151 \times 10^8 C = -94 \times 10^8 C + 2$

$C = 82\ pfd \Rightarrow 56\ pfd$

$X_C = \frac{1}{2\pi f\ 82 \times 10^{-12}} = 194 \Rightarrow 284$

$-149 = 2\pi f L - 194$

$L = 0.72\ \mu h \Rightarrow 1.22$

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DATA FROM BOB FRANK LAB NOTEBOOK 11-18-74

f	Rin	Xi
90	3,4	-243
100	4,0	-207
110	5,0	-173

$X_i = 207\Omega$

$\frac{dX_i}{df} = 3.5\ \Omega/KHz$

$3.5 \times 10^{3} (2\pi f^2 C) = -207 \cdot (2\pi f) C + 2$

$C\ 220 \times 10^{9} = -1300 \times 10^{5} C + 2$

$C = 5700\ pfd$ $= 5600$

$X_C = \frac{1}{2\pi f\ 57 \times 10^{-12}} = 279$ $\Rightarrow 284$

$-207 = 2\pi f L - 279$

$L = 1.15\ \mu h$

For Topload feed vertical up from ground

$100\ KHz = f_0 = \frac{1}{2\pi\sqrt{LC}}$ $\frac{dx_i}{df} = \frac{65.5}{10\ KHz}$ $R_{in} = 20\Omega$

$6.55 \times 10^{-3} = 2\pi L + \frac{1}{2\pi f^2 C}$

$628K = \frac{1}{\sqrt{LC}}$

$.39 \times 10^{12} = \frac{1}{LC}$

$6.55 \times 10^{-3} = 2\pi \frac{1}{C\ .39 \times 10^{12}} + \frac{1}{2\pi f^2 C}$

$6.55 \times 10^{-3} = (1.6 \times 10^{-11} + 1.60 \times 10^{-11}) \frac{1}{C}$

$C = \frac{3.2 \times 10^{-11}}{6.55 \times 10^{-3}} = 4900\ pfd$

$L = \frac{1}{4{,}900 \times 10^{-12} (.39 \times 10^{12})}$

$L = .52\ \mu h$

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11/19/74

calculate setting on bridge for 150pf for 10 MHz

$150pf;\ \frac{4000-X}{10} = 106 = \frac{1}{2\pi f\, 150\times10^{-12}}$ $X = 2940\Omega$ $\pm 1\%$ ~~% R~~ tolerance of cap

$100pf;\ \frac{4000-X}{10} = 159$ $X = 2410\Omega$ $\pm .01\%$

$82pf;\ \frac{4000-X}{10} = 194$ $X = 2060\Omega$ $\pm 1\%$

set Null on Bridge using 150pfd

Null	Reading
4000	2800
3800	2630
~~30~~ 4200	3060
~~[illegible]~~	
4100	2940

check 100pfd → 2410 Ω

check 82pfd → 2040 Ω

5 MHz antenna measurements

f	Reading	Rin	Xi
5.5	2190	21.9	329
5.0	2200	28.0	360
4.5	2200	32.0	400

$X_i = -360 \quad dX/df = 71$

$71\times10^{-6}/(2\pi f^2 C) = -360(2\pi f C) + 2$

$11147\times10^{6} = -11304\times10^{6}C + 2$

$2245/10^6 C = 2$

$C = 89pfd,\ X_c = 358\Omega$

$L = 0$

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Bridge input voltage 6 volt pp 11/19/74
Null 4100 Ω

f	Read	Rin	Xi
11	2700	18.6	118
10	2600	13.4	140
9	2450	12.4	172

$\frac{dX_i}{df} = 27 \times 10^{-6}$ $X_i = -140$

$27 \times 10^{-6}(2\pi f^2 C) = -140(2\pi f C) + 2$
$169 \times 10^8 C = -88 \times 10^8 C + 2$
$C = 78\,pfd$, $X_C = 204$
$-140 = 2\pi f L - 204$
$L = 1.02\,\mu h$

Braid To Bridge via Top connector; Table grounded at Top connector

11	2730	23.0	115
10	2610	14.4	139
9	2500	12.5	167

$\frac{dX_i}{df} = 26 \times 10^{-6}$ $X_i = -139$

$26 \times 10^{-6}(2\pi f^2 C) = -139(2\pi f C) + 2$
$163 \times 10^8 C = -86 \times 10^8 C + 2$
$C = 80\,pfd$, $X_C = 199$
$-139 = 2\pi f L - 199$
$L = 0.95\,\mu h$

Braid To Top connector, #16 wire ground
Bridge Null 4100, 6 v pp

11	2770	19.9	112
10	2600	13.0	140
9	2470	13.3	170

$dX_i/df = 29 \times 10^{-6}$ $X_i = -140$

$29 \times 10^{-6}(2\pi f^2 C) = -140(2\pi f C) + 2$
$182 \times 10^8 C = -88 \times 10^8 C + 2$
$C = 74\,pfd$, $X_C = 215$
$-140 = 2\pi f L - 215$
$L = 1.2\,\mu h$

RAIN 11/20/74

CONNECTOR connector directly at ~~[illegible]~~ Table 11/21/74
#10 wire used To ground connector ~~To~~ shell To Bridge

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EQUIPMENT LOG FOR MULTI-TOWER STUDY
(Subsystem, Major Unit, Etc.)

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11/22/74

Grounding Bridge to grounded connector to null Bridge

Bridge E = 8 vpp

f	Reading	Rin	Xi
11	2570	7.7	130
10	2470	9.0	153
9	2410	11.5	177

$X_i = -153\ \Omega$

$\frac{dX_i}{df} = 23.5\ \Omega/MHz$

Grounding Bridge at Bridge ground to Null

f	Reading	Rin	Xi
11	2620	10.2	125
10	2580	11.0	142
9	2430	14.0	174

$X_i = -142\ \Omega$

$dX_i/df = 24.5\ \Omega/MHz$

AT Connector

$23.5 \times 10^{-6}(2\pi f^2 C) = -153(2\pi f C) + 2$

$148 \times 10^8 C = -96 \times 10^8 C + 2$

$C = 82\ pfd$; $X_c = -194\ \Omega$

$-153 = 2\pi f L - 194$

$L = 0.65\ \mu h$

at Bridge

$24.5 \times 10^{-6}(2\pi f^2 C) = -142(2\pi f C) + 2$

$152 \times 10^8 C = -89 \times 10^8 C + 2$

$C = 83\ pfd$; $X_c = -192\ \Omega$

$-142 = 2\pi f L - 192$

$L = 0.80\ \mu h$

205' West of antenna Field measurement

$I = 25\ mv\ pp / 50\ mv/amp \times \frac{.707}{2} = .177\ amp\ rms$

Reading 48.5 db

$E = 48.5 + 36.5 = 85\ db = 17.8\ mV/m$

$R_r = \left[\frac{(17.8)\ 205/5280}{.177 \times 186.4}\right]^2 = 0.~~44~~\ \Omega$

SAD

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				11/22/74	

Measured series resonance frequency of antenna system with 6 Vp/p applied via amplifier to bridge

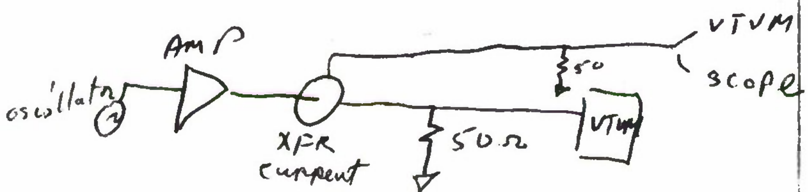
Balance Reactance $\frac{5000\,\Omega}{10}$

Null Reactance $\frac{5000\,\Omega}{10}$ at 1.950 MHz

Resistance less than 25 Ω but no distinct null

C Tomonlen

11/25



calibrate Current Transformer

5 Volts rms across 50 Ω resistor
.1 amp rms

scope 18 mV pp
meter 6.5 mV rms

calibration 18 mV pp/.1 amp = 6.5 mV rms/.1 amp

From 11/22

$I = \frac{25\,mVpp}{(18)}(.1) = .139\,amp\ rms$ $R_r = \left[\frac{17.8 \times 205/5280}{.139 \quad 186.4}\right]^2 = 0.71\,\Omega$

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[signature] 11/26/74

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY	ON	CUMULATIVE OPERATING TIME (4) STANDBY	ON

4' Model 11-26-74

Field Strength Measurements at WEST 205' & 300', EAST 200'

1. Table ground connected to coax shield of Antenna Input signal cable & stake

Data: Antenna Current Transformer output terminated in 50Ω	Field Strength in db plus loop loss of 36.5 db - above 1μV/m	Location	Frequency 9.93 mHz
10 mV	48.5+36.5=85	W 205	9.93 mHz
10 mV	44+36.5 = 80.5	W 300	|
10 mV	48.5+36.5 = 85	E 200	9.93 mHz
5 mV	41.9+36.5 = 78.4	E 200	9.93 mHz

2. Table ground connected only to stake

10 mV	54.5 + 36.5 = 91.0	E 200	9.93 mHz

Data Reduction:
85 db above 1μV/meter = 17.9 mV/meter
80.5 db above 1μV/meter = 10.6 mV/meter
78.4 db above 1μV/meter = 8.3 mV/meter
91 db above 1μV/meter = 35.5 mV/meter

10 mV rms transformer output $\equiv I = 10 \frac{.1A}{6.5mV}$

$I_A = .1538$ Amperes

$$R_r = \left[\frac{V/m \times d}{I_A \times 186.4}\right]10^3 = \left[\frac{17.9 \times 205/5280}{.1538 \times 186.4}\right]10^3 = .587\,\Omega$$

← for 205 W

Calculated R_r ohms	Location	Remarks
.587	W 205	Full current (.1538 A) Table ground to signal cable
.441	W 300	↓ ↓
.587	E 200	
.481	E 200	½ current
2.2	E 200	Full current, table grounded to stake

Conclusion: Not grounding table directly to signal input adds 6db of field strength, increases R_r by 4.

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Remove 4' model, install 3' model 11/27/74

expected results 300' ft

$X_i = -344\,\Omega$ $\frac{dX_i}{df} = 475\ \Omega/\text{kHz}$ $R_i = 4.1\,\Omega$

$R_r = 0.492$

Field Meter 205 feet West

$E = 43.8\,db + 36.5 = 80.3\,db = 10.4\,mV$

Input 10 mV rms ; sensi = 6.5 mV/.1 amp

$I_{in} = .154$ amp rms

$$R_r = \left[\frac{10.4 \times 205/5280}{.154 \times 186.4}\right]^2 = 0.20\,\Omega$$

Distance West ft	Reading E db	Corrected E db	E mV	R_r Ω
150	44.1	80.6	10.7	0.11
200	42.6	79.1	9.0	0.14
250	41.7	78.2	8.2	0.18
300	39.5	76.0	6.3	0.17
350	38.6	75.1	5.7	0.17

f MHz	Reading Ω	X_i Ω	R_i Ω
9	1420	-287	≈ 1
10	1430	-257	≈ 1
11	1580	-220	≈ 1

$X_i = -257\,\Omega$

$\frac{dX_i}{df} = 33.5\,\Omega$

$33.5 \times 10^{-6}(2\pi f^2 C) = -257(2\pi f\, C) + 2$

$210 \times 10^8 C = -161 \times 10^8 C + 2$

$C = 54\,pfd$ $X_C = -295\,\Omega$

$-257 = 2\pi f L - 295$

$L = 0.61\,\mu h$

$47.5 \times 10^{-6}(2\pi f^2 C) = -344(2\pi f C) + 2$

$298 \times 10^8 C = -216 \times 10^8 C + 2$

$C = 39\,pfd$ $X_c = -408$

$-344 = 2\pi f L - 408$

$L = 1.0\,\mu h$

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REMOVE 3' model, install 6.25' model 11/27/74

6.25 ft should be $X_i = -25\Omega$ $\frac{dX_i}{df} = 26\ \Omega/kHz$ $R_i = 2.5\Omega$

$R_r = 2\Omega$ $\left[C = 110\text{ pfd}\right.$ $\left.L = 1.9\mu h\right]$

$26\times10^{-6}(2\pi f^2C) = -25(2\pi fC)+2$
$163\times10^{8}C = -16\times10^{8}C+2$
$C = 112\text{ pfd}$, $X_c = 142\Omega$
$-16 = 2\pi fL - 142$
$L = 2.0\mu h$

f	Reading	Xi	Rin
MHz	Ω	Ω	Ω
9	3670	-37	1
10	3840	-16	2
11	4150	+14	2
11	115	+10	3.6

$X_i = -16$ $\frac{dX_i}{df} = 23.5\ \Omega/MHz$

$23.5(2\pi f^2C) = -16(2\pi fC)+2$
$148\times10^{8}C = -23\times10^{8}C+2$
~~$C = 117$ pfd, $X_c = 136$~~
~~$-16 = 2\pi fL - 136$~~
~~$L = 1.9\mu h$~~ SAD

— using inductance null method — zero reactance dial

$148\times10^{8}C = -10\times10^{8}C+2$
$C = 127\text{ pfd}$
$X_c = 125$
$-16 = 2\pi fL - 125$
$L = 1.7\mu h$

10 mv input = .154 amps rms

Distance west	E uncorr.	E corr	E corr	Rr
ft	db	db	mV	Ω
205	56.3	92.8	44.1	3.6
250	55.3	91.8	39.1	4.2
300	52.9	89.4	29.1	3.3
300	53.2	— with Truck in field		

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EQUIPMENT LOG FOR MULT-TOWER STUDY
(Subsystem, Major Unit, Etc.)

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Relate To Model	4' Ac.T.	400'	3'	300'	6.25'	625		11/29/74	
Cap-Equiv pfd	82	56	54	39	127	110			
L μh	0.65	1.2	0.61	1.0	1.7	1.9			
R_{in} Ω	9	4	71	4.1	72	2.5			
R_r Ω	0.5	1.07	0.18	0.49	3.5	2.1			
f_0 MHz	19.5 21.5	19	28	27.5	10.9	10.7			
R_r Ω	1.8	1.07	0.52	0.49	10	2.1	New calibration		

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(Subsystem, Major Unit, Etc.)

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12/2/74

1. 625' MODEL DAMAGED IN RAIN STORM, NIGHT OF DEC 1/2 REPAIRED

2. ERECTED 300' MODEL TO DETERMINE IF GR BRIDGE TYPE 1601 A IS SUITABLE FOR MEASUREMENT AS A CHECK ON THE 916 A BRIDGE FOUND POOR SENSITIVITY AND COULD NOT NULL THE BRIDGE WELL. COULD NOT DETERMINE REACTANCE OF A 150pf CAP.

3. REMOVED 300' MODEL.

12/3/74

1. INSTALLED 625' MODEL, BUT COULD NOT INSTALL TOP LOADING ELEMENTS AND GUY DUE TO HIGH WINDS.

2. MEASURED INPUT IMPEDANCE OF 625' MODEL WITHOUT TOP LOADING
RESULT: AT 10 MHz

$X = \frac{5000-1100}{2} = 340\,\Omega$ $R = 11.2\,\Omega$, PREVIOUS MEASUREMENT

~~[illegible]~~

OF R YIELDED $2\,\Omega$ AT 10 MHz (see page 19)

NOTE: BOTH 400' AND 625' MODEL READ NEAR $10\,\Omega$ NOW. SUSPECT BRIDGE IN ERROR.

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EQUIPMENT LOG FOR ______
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ R Rosenbaum

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12/4/74

PERFORMED BENCH MEASUREMENT WITH 416A BRIDGE

INPUT TO BRIDGE	FREQUENCY Hz	U.U.T	BRIDGE MEASUREMENT	WITH D.C. METER
1.4 Vp/p PURE SINE	10,002.6	10 Ω CARBON RESISTOR	10.5 Ω	10.6 Ω
6 Vp/p SOME DISTORTION	10,002.6	10 Ω CARBON RESISTOR	10.6 Ω	10.6 Ω
✓	10,001.3	55.3 BNC RESISTOR #1	60.5 Ω	70 Ω
✓	10,002.6	50.0 " " #2	68.0 Ω	66.7 Ω
✓	10,002.6	36 pf MICA CAP	−j 390 R = 0	CALCULATION 40.8 pF
✓	10,002.6	150 pf MICA CAP	−j 100 R = 0	CALCULATION 159.24 pF
✓	10,003	300' MODEL WITHOUT TOP LOADING ON METAL SHIELD	X = −j 231 R = 0	
✓	10,003	400' MODEL #1 WITHOUT TOP LOADING ON METAL BASE	X = −j 200 R = 12	
✓	10,003	2 OTHER 400' MODELS NEVER USED	X = −j 200 R = 0−1 Ω	
✓	10,000	625' MODEL ON BASE NO TOP LOADING	X = −j 200 R = 4 Ω	

SUSPECT THOSE UNIT WHICH WERE IN RAIN HAVE HIGH R

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12/4/74

FOR SERIES $r = 12\Omega$, SERIES $X_C = -j200\Omega$ and $C = 80pf$

PARALLEL $R = r\left[1 + \left(\frac{1}{wCr}\right)^2\right] = 12\left[1 + \left(\frac{1}{2\pi\, 10^7\, 80 \times 10^{-12}\, 12}\right)^2\right] = 3275\Omega$

Suspect wooden base causing high impedance short between rod and table top. Will replace one base with plexiglass base.

12/5/1974

Recalibrate Field intensity Meter's loop at UNCAL
@ 10 MHz 21.5 db ; add 20 db for substitution ~~[illegible]~~ measurements
had @ 10 MHz change to 0.5 db from a 2 db
install 3' antenna
$I_i = 0.154$ amp rms

Distance West ft	E db	Ecorr. db	E mV	R_r Ω
100	49.6	91.6	38.0	0.63
150	45.9	87.9	24.5	0.59
200	42.4	84.4	16.3	0.46
250	40.7	82.7	13.8	0.52
300	36.9	78.9	8.9	0.32

Visit from Major Harden. USAF 12/5/1974

Reading $I_i = 0.154$ amp rms
E @ 205' west 42.9 db + 42.0 84.9 db correct = 17.6 mV, $R_r = 0.54$
solder Top bushing to Post
E @ 205' west 42.9 + 42.0 = 84.9 db correct = 17.6 mV, $R_r = 0.54\Omega$
NO EFFECT

IMPEDANCE CHECK

9 MHz	$X_i = 1410$	$R_i \approx 0$	$X_i = -288\Omega$
10 MHz	1480	≈ 0	-252Ω
11 MHz	1440	≈ 0	-233Ω

$\frac{dX_i}{df} = +27.5\ \Omega/MHz$

$27.5 \times 10^{-6} (2\pi f^2 C) = -252 (2\pi f C) + 2$

$172 \times 10^8\, C = -157 \times 10^8 C + 2$

$C = 61\,pfd$ $X_C = -261$

$-252 = 2\pi fL - 295$

$L = .68\,\mu h$

NO EFFECT OF SOLDERING TOP BUSHING

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see page 20 12/6/74

calculate Rr based on new calibration

data from 11/27/74 6.25' antenna
@ 205'; E = 56.3 + 42 = 98.3 db = 83 mV Rr = 12 Ω
@ 300'; E = 52.9 + 42 = 94.9 db = 56 mV Rr = 12.3

data from 11/26/74 9 antenna
@ 205'; E = 48.5 + 42 = 90.5 db = 33.5 mV Rr = 2.0 Ω
@ 300'; E = 44.0 + 42 = 86 db = 20 mV Rr = 1.6 Ω

install 6.25' antenna; I_i = 0.154 amp rms 12/6/74
west @ 250'; E = 54 db uncorrected 12/6/74
rotate field loop 90° ⊥ to antenna
E = 15 db uncorrected
rotate loop back 54 db uncorrected

Place ~~dumm~~ dummy load (82 pfd + 50Ω Resistor)
E reading 0.0 db no effect;

check-? impedance

freq	X_i Reading	R_i	X_C
9	3820	2.4	-47
10	3800	3.9	-20
11	4200 (L)	5.7	+18
on L scaling 11	140 (L)	4.6	+13

$\frac{dX_i}{df} = +27.5$

$27.5 \times 10^6/(2\pi f^2 c) = -20(2\pi f c) + 2$

$193 \times 10^8 C = -126 \times 10^8 C$

$C = 67$ pfd ; $X_C = 238$

$-20 = 2\pi f L - 238$

$L = 347\ \mu h$

6.25' Antenna

Distance West FT	E db	E_{corr} db	E mV	Rr Ω
205	56.3	98.3	72	9.5
250	54.4	96.4	65	10.0
300	52.1	94.1	50.5	11.3
350	51.2	93.2	46	11.5

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(Subsystem, Major Unit, Etc.)

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12/9/73

I_i = .154 amp rms ; No radials just the 6.25' post

Dist	Read-E	Ecorr	E	Rr
205 west	44.1 db	86.1	20 mV	.7 Ω
300'	40.9	82.9	13.9	.76

Repeat

200	44.0	86	20	.69
250	42.5	84.5	17	.78
300	40.5	82.5	12.5	.61
300 south-west	40.0	82	12.0	.6 est

expect 1.4

Repeat with 6.25' center post add 12 - 4' long radials to 6.25' base

205 west	54.5	96.5	67	8.2
300	51.4	93.4	47.5	8.9

Impedance Measurements

freq MHz	X Ω	Ri Ω	Xi Ω
9	2240	0.9	196
10	2510	1.4	149
11	2490	2.0	137

$\frac{dX_i}{df} = 29.5\ \Omega/MHz$

$10^{-6}\, 29.5\,(2\pi f^2 C) = 149\,(2\pi f C) + 2$

$185 \times 10^8 C = 94 \times 10^8 C + 2$

$C = 72\,pfd \quad X = -221\,\Omega$

$-149 = 2\pi f L - 221$

$L = 1.1\,\mu h$

$f = \frac{1}{\sqrt{LC}\,2\pi} = \frac{1}{\sqrt{1.1\mu\, 72p}\;2\pi}$

$f = 17.9\,MHz$

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EQUIPMENT LOG FOR MULTI TOWER STUDY G. Tesenbu
(Subsystem, Major Unit, Etc.)

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12/10/74

1. Set up 625' Antenna without top loading.
Radiated at 9.93 nH between 10:30 AM and 1:30 pm with $I = .154$ A
Measured field intensity at 200' SW : 45.0 db

2. Added 12 radials, 4' to 625' antenna.
Radiated from 1:30 pm to 3:30 pm at 9.93 nH with $I = .154$ A
Measured field intensity at 200' SW : 56db

Repeat of step 2 with table ground and all instrument strap ground removed from stake, still 56db.

Discussion: Configuration for 1 should yield 1.6Ω per Devaney, et al
" 2 " " (1.6Ω)1.85 or 2.96 per Devaney figure 20

Calculated results for 1. Field intensity = 45db + 42db assumed antenna factor
= 87db above 1μv or 22mv

$$R_r = \left[\frac{22 \times 200}{.154 \quad 5280}\left(\frac{1}{186.6}\right)\right]^2 = .841\,\Omega$$

Calculated result for 2 $R_r = 11.12\,\Omega$ $E = 56+42 = 98$db above 1μV

These measurement repeat the performance on 12/9/74

3. Repaired lead in connector on 625' model ~~[illegible]~~ prior to testing

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12-11-74

6.25' centerpost 12 - 4' Radials

Field measurements @ 9.93 MHz I_i = 0.154 amp rms

(1) VSWR = 8 @ I_i = 22.2 mv on Bellantine
I_i = .154 amperes (10mv) @ 250' west E = 52.8 db = 94.8 db
R_r = 8.2 Ω E = 55 mv

(2) @ 9.14 MHz
VSWR = 4.5 with I_i = 16.4 mv on Ball. [E = 51.6 db]?
@ 250' west I_i = .154 E = 55.5 db 97.5 db = 75 mV ; R_r = 15 Ω

(3) Repeat 1 E = 52.9

(4) Remove Current XFMR E = 52.3

(5) Remove Coupler E = 52.3

(6) Replace current XFMR E 52.7

(7) Remove Matchbox I_i = initially .6 mv
Set 10 mv E = 52.3

(8) Replace Matchbox & coupler
initially I_i = 16.6 mv
set to I_i = 10 mV E = 52.8

Move center post 7.8 in below Table
set I_i = .154 amp rms ground with co-ax to center hole connector
E = 50.3 + 42 = 92.3 db = 41 mV
R_r = 4.6 Ω

clip lead ground to current XFMR
E = 53.5, 59.5 mV R_r = 9.7 Ω

Pull ground off at center
E = 56.5 db, 67 mV R_r = 12 Ω

Move centerpost down to get 4' Tower height
I_i = .154 amp @ 205' west, E = 49.7 db 91.7 db 39 mV R_r = 2.8 Ω

Place shield ~~on~~ around center post below Table
E = 48.7 + 90.7 db 35 mv R_r = 2.2 Ω

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 1 SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR MULTI- TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______

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12/11/74

Place al shuts on west facing side of platform connected To The Table Top.

Before @ 205' west I_i = .154 amp rms
E = 54.1 db

After @ E = 54.4 db
@ 205' southwest
E = 53.9 db
@ 205' south E = 53.8 db
No apparent effect

12/12/74

@ 205' west ground braid To power XFMR
4' center Tower only I_i = .154 amp rms, plastic base

f = ~~10 MHz~~ 9.93 MHz, E = 39.3 + 42 = 81.3 db = 11.3 mV
Rr = 0.23 Ω

f = 15.5 MHz equivalent to 6.25' tower
E = 45.8 + 41 = 86.8 db = 21.9 mV
Rr = 0.88 Ω

add 4' - 12 Top load elements
f = 9.9 MHz, E = 56.6 + 42 = 98.6 db = 85 mV
Rr = 13 Ω

f = 15.5 MHz E = 56.4 + 41 = 97.4 db = 73 mV
Rr = 9.8 Ω

Direct Table Top ground To stake,
@ 9.93 MHz E = 49.6 db
E = 50.1 db
@ 15.5 MHz E = 56 db

Place amplifiers on top of Table cart
@ 9.93 MHz E = 49.9 db
@ 15.5 MHz E = 57.1
No Effect Appartent

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@ 205' west I_i = .154 amp rms 12/12/74
4' tower with top loading elements
f = 9.93 MHz
E = 50.2 db
Remove ground strap E = 50.3
from post
Remove ground strap from cart E 50.3 db
15.5 MHz E = 59 db.
connect ground strap to cart E = 59 db
connect ground strap to ground stake E = 59. db
12/13/74
W. E. Gustafson of U.S. Navy Electronics Laboratory of San Diego, Calif.
indicates a "pedestal" effect of the antenna on the table to account for the high values of radiation resistance

planning to use ground plane (al mesh) with stake on cement. ~~with~~ will place test equipment remote from antenna

12-18-74

Place 4' antenna 12 - 4' radials on ground-cement

Distance (est)	ft.	E db	E corrected	E mv/m	Rr (est)	
(134)	136	49.2 +42 =	91.2	36	(.95)	1.04
(180)	186	45.6	87.6	24	(.81)	0.90
(230)	236	43.7	85.7	19.3	(.86)	0.91
(280)	286	41.0	84.0	15.9	(.86)	0.90

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12-18-74

Distance ft	E db	E corr	E mv	f MHz	height ft	Rr Ω	Rr Refl. to 4' height
≈ 180	47.6 + 41 = 88.6		27.0	11.0	4.4	≈ 1.03	≈ .86
≈ 180	48.8 + 40.8 = 89.6		30.4	12.0	4.8	≈ 1.3	≈ .90
≈ 180	47.9 + 42 = 89.9		31.3	13.0	5.2	≈ 1.4	≈ .83
≈ 180	50.3 + 41 = 91.3		36.7	14.0	5.6	≈ 1.9	≈ .97
≈ 230	45.2 + 41 = 88.6		27.0	14.0	5.6	≈ 1.7	
≈ 180	56.5 + 41 = 97.5		74.9	16.0	6.4	8.5	≈ 3.3
≈ 180 Previous data	57 + 41 = 98		79.4	15.5	6.2	9.5	≈ 3.9
				10	4.0	.85	.85
				≈ 15.5	6.2	8.5	3.5
				≈ 10	5.7	9.2	2.9

Distance ft	Edb db	E corr	E mv	f MHz	Rr (est) Ω	
est (130) 136	59.1 + 41 =	100.1	100	15.5	(7.3)	8.1
(180) 186	56.8	97.8	78	15.5	(8.6)	9.2
(230) 236	54.8	95.5	60	15.5	(8.2)	8.6
(280) 286	52.8	93.5	46	15.5	(7.2)	7.6

12-19-74

Place ~~XFT~~ CURRENT TRANSFORMER UNDER PLASTIC BASE WITHOUT GROUND BOX SHIELD. PLACE MATCH BOX 4' AWAY FROM CENTER POST I_i = .154 amp rms @ 186'

Freq MHz	Distance feet	Edb db	Edb corr	E mv	Rr Ω
10 MHz	186	47.2 + 42 =	89.2	28.8	1.25
15.5 MHz	186	51.2 + 41 =	92.2	40.8	2.5

Measured distances accurately, repair connect at base

Move equipment inside, check current XFMR calibration

Dummy resistor load with ~~antenna~~ XFMR around center post

$\frac{V_R}{R} = \frac{2.9V}{34.7\Omega} = 84ma$ Reading 5.4 mV sensitivity @ 10 MHz .065 V/a

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12/19/74

$\frac{V_R}{R} = \frac{4.8}{34.7} = 138$ ma

Reading = 10mV

sensitivity @ 15.5 MHz .072

Must check again - suspect setup - pickup problems

Using Two Terminations one at antenna & one at meter 12/20/74

@ 10 MHz
5 V across 34.7 Ω
I = 144 ma
XFMR Reading = 9.1 mV
current XFMR sensitivity .063 V/a

@ 15.5 MHz
7.95 V across 34.7 Ω
I = 229 ma
XFMR Reading = 14.6 mV
current XFMR sensitivity .064 V/a

4' + 2 radial antenna
add ground plane screen (16' x 13' mesh) - remote driving XFMR at base 4' lead to matchbox

@ 186 deg., .154 amp rms in
@ 10 MHz E = 51.2 + 42 = 93.2 db, 46 mV Rr = 3.2 Ω
@ 15.5 MHz E = 57.1 + 41 = 98.1 db, 80.4 mV Rr = 9.8 Ω

Terminate remote cable with 50 Ω
@ 15.5 MHz E = 55.5 + 41 = 96.5, 67 mV Rr = 6.8 Ω

Retune with different cable positions (matchbox to antenna)
Ii = 10.5 mV = .162 amp rms E = 56 + 42 = 98 db 79.4 mV Rr = 8.6 Ω
Ii = 8.5 mV = .131 amp rms E = 53 + 41 = 94 db 50.1 mV Rr = 5.2 Ω

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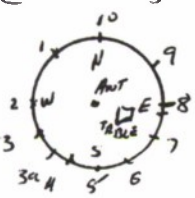
Ground center post cable at center to screen 12-20-74
@ 15.5 MHz E = 56.7 + 41 = 97.7 db 77 mV R_r = 9.0 Ω
@ 10.0 MHz E = 49.1 + 42 = 91.1 db 36 mV R_r = 2.0 Ω

Remove screen
@ 10 MHz E = 47.8 + 42 = 89.8 db 31 mV R_r = 1.5 Ω
@ 15.5 MHz E = 56.3 + 41 = 97.3 db 74 mV R_r = 8.3 Ω

move 45° to West 206' away
E = 54.5 + 41 = 95.5 db 59.5 mV R_r = 6.6 Ω
cable (loop to fieldmeter) broken repair
12/23/74



AT 9.93 MHz .154 amp rms grounded at stake

Location	Distance	Direction	E db		E mV	R_r (Ω)
1	205'	45° NW	45.2 + 42 =	87.2	23.0	0.97
2	206	W	45.4	87.4	23.3	1.01
3	210	S 35 from W	44.3	86.3	20.8	0.83
4	210	S 60 from W	45.2	87.2	23.0	1.02
5	209	S	44.9	86.9	22.1	0.93
6	206	E 30 from S	47.6	89.6	29.7	1.60
7	205	E 45 from S	46.2	88.2	26.0	1.24
8	204	E	45.0	87.0	22.4	0.91
9	200	N 45 from E	45.4	87.4	23.3	0.95
10	203	N	44.4	86.4	21.1	0.80
1	205	45° NW	45.2	87.2	23.0	0.97

@ 15.5 MHz @ 205' (45) N-W E = 52.5 + 41 = 93.5 db 48 mV
R_r = 4.2

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Add ground mesh 12-23-74

Location	Distance	Direction	Edb		Emv	Rr(Ω)
1	205	(45°) N-W	48.2+42=	90.3	33.0	2.0
2	210	W	48.5	90.5	33.5	2.2
3a	211	S 45 from W	47.7	89.7	30.5	1.8
5	211	S	48.1	90.1	31.9	2.0
6	206	E 30 from S	49.2	91.2	36.5	2.5
7	205	E 45 from S	49.7	91.7	38.2	2.7
8	201	E	48.1	90.1	31.9	1.8
9	198	N 45 from E	49.4	91.4	37.5	2.4
10	200	N	48.2	90.2	32.6	1.9
1	205	(45°) N W	48.2	90.2	32.6	2.0

must ground current XFMR at its case (@ located to closest ground) 12-26-74

6.25' 12-4' Radials I = .154 amps rms @ 9.93 MHz

Location	Distance	~~Vin~~ E+42=	Edb	Emv	Rr without Mesh (oscillator & Vin=40Vpp)	E+42=	Edb	Emv	Rr with Mesh (oscillator & Vin=56Volt pp)
1	206	52.6	94.6	53.8	5.4	56.3	98.3	82.4	12.6
2	209	53.2	95.2	57.0	6.2	56.1	98.1	80.4	12.3
3a	211	51.9	93.9	49.5	4.8	54.4	96.4	66.2	8.5
5	210	51.8	93.8	49.0	4.6	55.3	97.3	73.2	10.3
6	205	53.9	95.9	62.5	7.2	56.5	98.5	84.4	13.1
7	205	53.1	95.1	56.9	5.9	56.2	98.2	81.4	12.2
8	201	51.7	93.7	48.5	4.2	55.7	97.7	77.0	10.5
9	199	54.8	96.8	69.5	8.4	55.7	97.7	77.0	10.3
10	201	53.8	95.8	62.0	6.8	55.6	97.6	76.2	10.3
1	206	53.0	95.0	56.2	5.9	56.6	98.6	85.4	13.5

with mesh Add small coil for match box (3.3 μh) circuit tuned @ 10.3 MHz

@9.93 MHz I = 3.2 mV = 49 ma rms

@206' E = 45.9 + 42 = 87.9 db = 24.7 mV

$R_r = 11.2\ \Omega$

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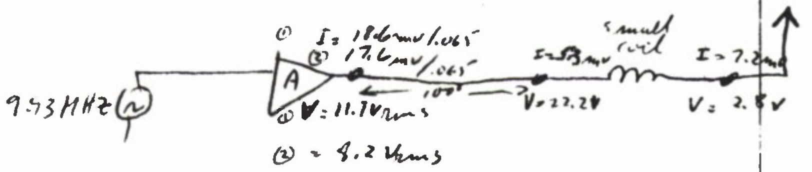	6.25' antenna 12-4' radials ground mesh			12/27/74	

6.25' center post w/ screen mesh on cement
I = 3.9mv = 60 marms E = 40.5 + 42 = 82.5 db = 13.3mV
Rr = 2.2 Ω

12-30-74

4' center Tower, No- Radials
@ 206' NW
@ 9.9 MHz I = 31mv = 48marms E = 32.8 + 42 = 74.8 db = 5.4mV
Rr = 0.56 Ω
@ 15.5 MHz I = 6.3 = 47 marms, E = 39.7 + 41 = 80.7 db 10.8mV
Rr = 0.55 Ω
Repeat @ 15.5 MHz I = 7.8mV = 120 marms E = 42.8 + 41 = 83.8 db = 15.5mV
Rr = 0.73 Ω Reposition Test equipment
@ 15.5 MHz I = 4.75 = 73 marms E = 37.2 + 41 = 78.2 db = 8.1mV
Rr = 0.54 Ω
shorten meter cable from 10' to 3'
@ 15.5 MHz I = 2.5mv = 38 marms E = 37.3 + 41 = 78.3 db = 8.2mV
Rr = 2.0 Ω
@ 9.93 MHz I = 2.5 - 2.4 mv = 38-40 marms E = 32.3 + 42 = 74.3 db = 5.2mV
Rr = 0.82 - 0.74 Ω
Bring test equipment to antenna on ground 8' away
@ 9.93 MHz I = 2.5 = 38.5 marms E = 33.3 + 42 = 75.3 db = 5.8mV
Rr = 0.99 Ω
isolated Test equipment with 3-2 60 Hz plug
E = 32 + 42 = 74 db = 5.0 mV
Rr = 0.76 Ω
@ 15.5 MHz I = 2.5 = 38.5 marms E = 38.8 + 41 = 79.8 db = 9.7mV
Rr = 2.8 Ω

SECURITY CLASSIFICATION (THIS PAGE)

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EQUIPMENT LOG FOR Multi Tower Study (Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tosenbaum

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1-2-75 OPERATION AT 9.930 MHZ	14:30 to 15:45		✓		

Erected 6.25 ft rod antenna without radials, fed from amplifier located appr. 8' from antenna. Measured current flow with current transformer around rod above base $- I = (2.5\,mV)\frac{1\ amp}{63\,mV} = .038\,A$

Measured field strength 205 feet away NW. Field strength is ≃ 46-48 db + 42 db ≃ 90 db or $\frac{30\,mV}{meter}$. This abnormally high yielding $R_r = 30\,\Omega$

Decided to remote amplifier again.

1-3-75 OPERATION AT 9.930 MHz	0915 to 1200		✓		

Remote amplifier and current monitor 2231V
Current monitor loss for 110 feet of RG ~~58~~ cable is 1.65 db or 20%

Read $V_i = 2.5\,mV + 20\% \simeq 3\,mV$

$I = 3\frac{1}{63} = .048\,A$

At 205 feet $E_{CW} = 40\,db + 42 = 82\,db$ above $1\,\mu v = 12.5\,mv$

$R_r = 2.94\,\Omega$ The expected ~~reading~~ $R_r = 1.6$ ohms

Rain terminated testing 13:00

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EQUIPMENT LOG FOR Multi Tower Study
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ Rosenbaum

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1-6-75 OPERATION AT 9.930MHz	8^{45}-13^{15}		✓		

6.25 ROD NO TOP LOADERS $I_{IN} = 2.5$ mv rms measured remote + 20% line

$E_{FIELD} = 40DB$ 205'

$R_r = 2.94\Omega$ same as on 1/3/75

With same current $\left(\frac{2.5 \text{ mv rm}}{6.5(10)}\right)$ radials were added 2 at a time and field strength recorded, $d = 205$ ft

			R_r calculated
a) 2 radials NW facing loop	 	E = 41.3 db	4.3 Ω
b) 2 radials SW facing loop		E = 41.6 db	4.6
(c) 4 radials		E = 42.4 db	5.58 Ω
d) 6 radials		E = 43.2 db	6.64 Ω
(e 8 radials		E = 43.2 db	6.64 Ω

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EQUIPMENT LOG FOR Multi Tower Study (Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tesenbe

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1-7-74 OPERATION AT 9.9300 MHz	11:15 to 3:15		✓		
	After severe rain fall			40°F	
6.25 ft Model NO TOP LOADERS , I = 2.5 mv +loss (~~.0337~~) = .046	E = 41 db +42 14.0 mv	R_n calc = 4.01			
10 TOP LOADERS I = 2.5 mv +loss	E = 43.3 db +42 18.4 mv	R_n = 6.94			
12 TOP LOADER I = 2.5 mv +loss	E = 43.2 db +42 18.2 mv	R_n = 6.79			
12 TOP LOADERS , LARGE SWIVELS	I = 2.5 mv	E = 43.1 db +42 = 18 mv		R_n = 6.64	
1-8-74 OPERATION AT 9.9300 MHz	9:15		✓	50°F warm & dry	
6.25 ft ANT NO TOP LOADERS I = 2.5 mv + loss	E = 40.0 db +42 = 12.5 mv R_n			= 3.2	
4 ft ANT NO TOP LOADERS I = 1.5 mv + 20% = (.028 A) ~~loss~~	E = 31 db +42 = 4.5 mv	R_n =		1.12 Ω	
4 ft ANT 12 TOP LOADER I = 2.5 mv + 20% I = (.046)	E = 36.8 db + 42 = 8.7			R = 1.55 Ω	

1-9-74 RAIN

RECHECKED CALIBRATION OF FIELD INTENSITY METER (NF 105 29244) AND FOUND READING HIGH BY 3.5 DB. CORRECT READING ARE ACHIEVED BY SETTING IMPULSE ATTENUATOR TO 76 DB INSTEAD OF 72.5 DB AT 10 MHz. THIS DISCOVERY MEANS THAT ALL PRIOR READINGS ARE NOW LOWER BY (3.5 DB) = x 1.5 AND RADIATION RESISTANCE COMPUTED BY 7 DB OR 2.25. THUS THE DATA TAKEN 1/6 AND 1/7 CALCULATES TO THESE NEW R_n's:

6.25' NO TOP LOADS	1.42 Ω	4' NO TOP LOADS	.55 Ω
6.25' 12 TOP LOADS	3.02 Ω	4' 12 TOP LOADS	.69 Ω

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EQUIPMENT LOG FOR MultiTower Study (Subsystem, Major Unit, Etc.)

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~~1-13-75~~ 1-10-75 OPERATION AT 99.300 MHz	9:30 - 12:30		✓		
	13:30 - 15:30		✓		
Measurement of Field intensity for 4' Model on top of table					
① No top load					
Current reading : 1.5 mV $E_{INT} = 30$ db	d = 250'	~~error~~ shield not in CW			
: 1.5 mV $E_{INT} = 24$ db	d = 250'	repeat			
② Top load : 2.5 mV $E_{INT} = 33.8$ db	d = 250'				
From the data R_r NO TOP LOAD =	1.54 Ω	expected .65			
R_r 12 TOP LOAD =	1.72 Ω	expected 1.07			
1-14-75 OPERATION AT 99.300 MHz	13:30 - 16:00		✓		
Measurement of Field intensity with 6.25' model 40 ft from table, current measured at table via 110' transformer cable - 24 top loaders.					
At 45° point					
Current Reading 2.5 mV ≡ .046 Amperes					
Field strength 38.8 db + AF 42 db = 80.8	= 11 mV				
distance = 205 ft					
R_r = 2.48 Ω					
Shut-down of Outdoor Testing Phase as of 1-~~20~~14-75 because of weather conditions, personnel absence and general cost effectiveness until 2-18-75					

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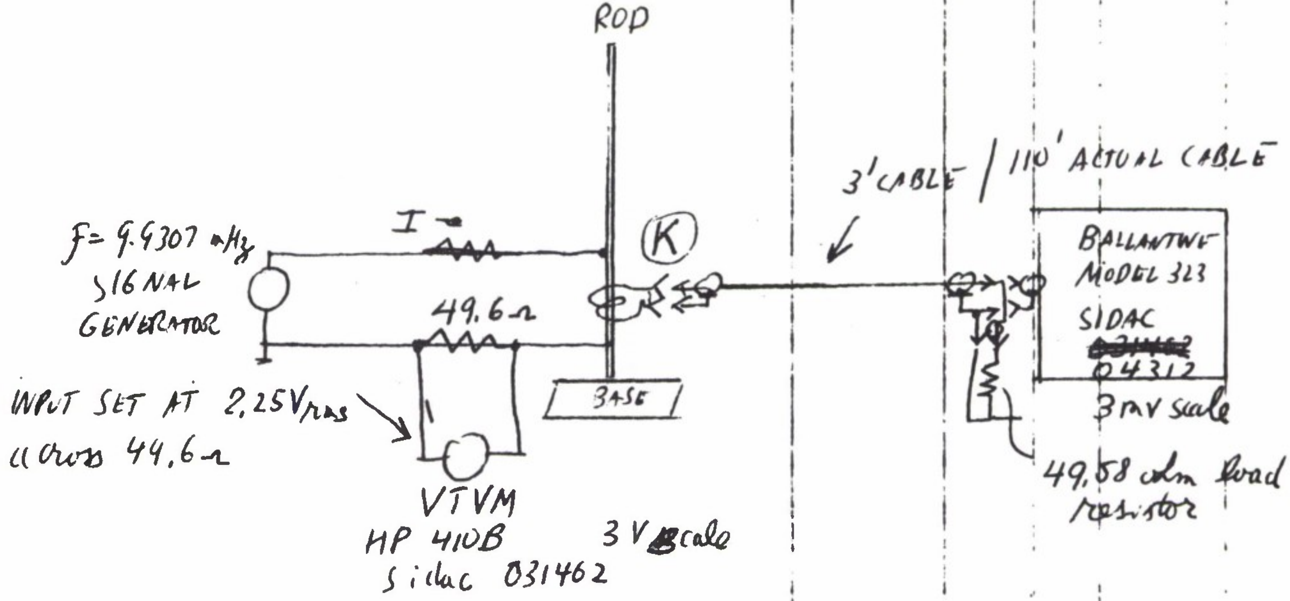
Recalibration of Current Transformer with 110 ft cable load		3/24/75 M Tesenbaum	J. Hansen		



$I = \frac{2.25V}{49.6\Omega} = 0.04536$ Amperes

Voltage across 49.58 Ω load : 2.46 mV with 3' cable
2.10 mV with 110' cable used in installation

Loss Ratio $\frac{2.46}{2.10} = 1.1714$ or 1.3 db

(Voltage across a 66.7 Ω termination = 3 mV with 3' cable
recheck prior data 2.55 mV with 110' cable.)

Transformer Ratio when measuring w. 110' cable and having 49.58 load resistor : $\frac{2.1\,mV}{.04536\,A} = \frac{.0021\,V}{.04536\,A} = .0463\,\frac{V}{A}$

$= 46.3\,\frac{mV}{A} = K$

With 50.5 Ballantine load $K = 1.02\,(46.3) = 47.2$

$= 47\ mV/A$

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EQUIPMENT LOG FOR MULTITOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ G. Tosenlum

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3/28/75 Clear, windy, ≈35°F 4' Model installed on table.
3/31/75 Clear, Winds 10-20 mph, Temp 35°-40°F, 4' model with 12 top loads

Impedance Measurements with 4 ft antenna, 12 top loaders,
Bridge recalibrated, Null detector is field intensity meter.

A.M READINGS

NULL AT 5000 Ω IS BETTER

f (kHz)	X_{atNULL} (X_N)	$X_{Reading}$ (X_R)	R	X_i ($\frac{X_N - X_R}{f}$)	Δ
9 *	5000	3000	0	$-j222.2$	39.7
10	5000	3175	0	$-j182.5$	28
11	5000	3300	10	$-j154.5$	
9 *	4000	2050	0	$-j216.7$	35.7
10	4000	2190	0	$-j181.0$	33.7
11	4000	2380	0	$-j147.3$	

PM READINGS

f	X_N	X_R	R	X_i	Δ	
9	5000	3100	0	$-j211.1$	31.1	61.1
10	5000	3200	0	$-j180$	30.0	
11	5000	3350	0	$-j150$		

BEST CONSISTENT DATA IS PM. BASED ON THIS: $X_C = \frac{f\frac{dx}{df} - X_i}{2} = \frac{10(30.5)+180}{2} = 242.5$

$X_L = X_i - X_C = -180 + 242.5 = 62.5$

or $C = 65.6\,pF$, $L = 0.99\,\mu H$

* TOP LOADERS LOOSE DUE TO WIND

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 1 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. [illegible]

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

3/31/75 continued
4' Antenna, 12 top loaders 4.5 ft from base
Slant feeding antenna, bottom plate insulated. Feed into one radial

PM

f	$X_{at NULL}$	X	R	X_i	Δ
9	5000	4200	2.2	$-j88.9$	48.9
10	5000	4600	3.3	$-j40$	58.2
11	5000	~~x~~ 5200	2.0	$+j18.2$	

Calculation: $C = 60.2 pF$
$L = 3.57 \mu H$
based on 48.9 slope

4-1-75 Weather, clear to cloudy, 40F to 55°F, WINDS CALM

CONTINUED SLANT FED IMPEDANCE MEASUREMENTS

AM

					Δ
9	5000	4200	2.2	$-j88.9$	48.9
10	5000	4600	2.4	$-j40.0$	
10.5	5000	4800	3.6	$-j14.0$	
f_R → 10.805	5000	5000	3.8	0	

Refined input to radial (not wrapped around eye-bolt)

9	5000	4100	2.4	$-j100$	55
10	5000	4550	3.6	$-j45$	
10.805	5000	4900	2.5	$-j9.25$	45
f_R 11.000	5000	5000	3.1	0	

Calculation based on slope = 50 Ω/MHz
$C = 58.4 pF$ $(-j272.5\Omega)$
$L = 3.62 \mu H$ $(j227.5\Omega)$

Insulating bushing and grounding mast

9.0	5000	4220	2.2	$-j86.1$	48.1
10.0	5000	4620	3.6	$-j38.0$	
10.9	5000	5000	3.6	0	41
11.0	5000	5100	3.0	$+j9.1$	

Average slope 41.9

$X_C = -j\frac{479+38}{2} = -j258.5$, $C = 61.6 pF$

$X_L = -j38 + j258.5 = 210.5$
$L = 3.51 \mu H$

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 1 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTIPLE TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Rosenbaum

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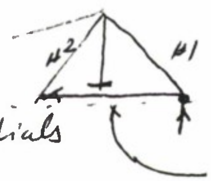
4/1/15 continued



Feeding into 2 radials
Mast grounded & insulated from radials

24" extra lead capacity calculated = 24pF

f	NULL	X	R_r	X_i	slope
9	5000	-j3850	.7	-j127.8	32
10	5000	-j4050	1.0	-j95.0	24.6
11	5000	-j4225	1.2	-j70.4	
14	5000	-j5000	5	0	

Av. slope = 28.3

$X_C = \frac{283+95}{2} = 189$

$C = 84pF - 24 = 60pF$

$X_L = +95 + 189 = j91\Omega \quad L = 1.45\mu H$

Radiation Measurement - Std 4ft - 12 radial antenna
Preliminary (first quick run), Field measurement = 30.9 db, Current meter 1.54mV
distance 205 ft

$E = 30.9db + (AF)42.0 = 72.9 db \text{ above } 1\mu v = 4.4mv$

$I = \frac{1.54mv \quad A}{47mv} = .033A$

$R_r = \left\{ (4.4)\frac{(205)}{5280}\frac{1}{.033}\frac{1}{186.4} \right\}^2 \times 10^3 = .77 \text{ ohms}$

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 1 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTIPLE TOWER ANTENNA
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tozenbaum

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

4/2/75 CLEAR-MOSTLY, CALM WINDS 40-50°F

1) STD 4' ANTENNA IS SET UP FOR RADIATION MEASUREMENT - 12 RADIAL, CENTER FEED
REMOTE GENERATOR AND METER.

Field Meter : 31.4 dB
Ant Factor : 42.0
73.4 dB = 4.7 mV

$I = 1.6\,mV \times \frac{1}{47} = .034\,A$

DISTANCE REMEASURED IS ACTUALLY 208',

$R = \left(\frac{4.7 \times 208}{5280 \times .034 \quad 186.4}\right)^2 = .85\,\Omega$

2) SLANT FEEDING INTO ONE RADIAL EXTENDED TO EYE HOOK.

First attempt CT is on ground open and wire feeding radial passes through it.

$e = 25.5$ dB
+42.0 AF
67.2 dB = 2.6 mV

$I = \frac{1.7}{47} = .036$

$d = 208'$

$R = .23\,\Omega$

Second attempt CT is in shielded box
$e = 31.8$ dB + 42 dB A.F. = 73.8 dB = 4.9 mV, $d = 208'$, $I = \frac{4.75}{47} = .101\,A$

$R = .105\,\Omega$

4/3/75 RAIN, WINDY, 40°F AM

NO OUTSIDE TESTING

MANUFACTURED 2 - 12-RADIAL TOP LOADINGS WITH # 41 GAUGE WIRES

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EQUIPMENT LOG FOR MULTIPLE TOWER ANTENNA
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) E Tixenbaum

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4/4/75 RADIATION TEST - RADIATED AT 944.7MHz 8:30AM - 12:00 NOON
13:30 - 16:00 PM

WEATHER: 35-38°F, WINDY, GUSTS 60 MPH,
ANTENNA MODEL SLIGHTLY DAMAGED IN WIND.
REMOVED 6' COAX USED PRIOR FOR BASE FEEDING
SLANT FEEDING INTO ONE RADIAL AND RADIATING AT 9.897 mHz,
CURRENT TRANSFORMER OPENLY WITH WIRE FEEDING RADIAL PASSING THROUGH IT.

① ANTENNA FLOATING

$e = 34$ db
less .2 db calibration
plus 42.0 db antenna factor
80.8 db = 10.96 mv

$i = \frac{6.9 \text{ mv}}{47} = .147$ A

$$R_2 = \left[\frac{10.96 \quad 208'}{.147 \quad 5280 \quad 186.4}\right]^2 = .25\,\Omega$$

2. ANTENNA GROUNDED

$e = 31$ db
$-$ .2 db cal
$+$ 42 db AF
72.8 db = 4.4 mv

$i = \frac{2.35 \text{ mv}}{47} = .05$ A

$$R_2 = \left[\frac{4.4 \quad 208}{.05 \quad 5280 \quad 186.4}\right]^2 = .346\,\Omega$$

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tesenbaum

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4/7/75 WEATHER: 35°-40°F, WINDOW, CLEAR

RADIATION FROM 9:00 AM TO 12 NOON, 13:15 TO 16:00 AT 9993 MHz
LOOP AT 45° POINT
SLANT FED ANTENNA INTO ONE RADIAL, NO TUNING BOX, TERMINATE INPUT COAX GROUND IN STAKE GROUND, CURRENT TRANSFORMER SHIELD GROUND ALSO TO STAKE, TOWER BASE GROUNDED.

(1) $e = 49.5\,db - .1\,db\ CALIB + 42.0\ AF = 91.4\,db = 37\,mV$

$I = \frac{17.5\,mV}{47} = .372\,A \qquad R = \left[\frac{37 \times 208}{.372 \times 5280 \times 186.4}\right]^2 = .44\,\Omega$

Repeated with shorter ground between feeder coax and stake.

(2) $e = 47\,db + 42\,db\ AF = 89\,db = 28\,mV$

$I = \frac{12.8\,mV}{47} = .27\,A \qquad R = \left(\frac{28}{.27} \times \frac{208}{5280} \times \frac{1}{186.4}\right)^2 = .48\,\Omega$

(3) Repeated (2) with base insulated

$e = 41.5\,db + .2 + 42 = 83.7\,db = 15.2\,mV$

$I = \frac{7.6\,mV}{47} = .162 \qquad R = \left[\frac{15.2}{.162} \times \frac{208}{5280}\ \frac{1}{186.4}\right]^2 = .39\,\Omega$

(4) Repeat (2) with base insulated and 2 radial feed

$e = 45\,db + .3 + 42 = 87.3\,db = 26\,mV$

$I = \frac{13.5\,mV}{47} = .287 \qquad R = \left[\frac{26}{.287}\ \frac{208}{5280}\ \frac{1}{186.4}\right]^2 = .37\,\Omega$

(5) Repeat (2) base grounded and 2 radial feed

$e = 41.5 = 15.2\,mV \qquad R = \left(\frac{15.2}{.172}\ \frac{.208}{5280}\ \frac{1}{186.4}\right)^2 = .35\,\Omega$

$I = \frac{8.1}{47} = .172$

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

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4/6/15, WINDY, 35-45°F, CLEAR

RADIATION FROM 8:30AM TO 13:00 AT 9.943 MHz AC 45° POINT

SLANT FED TEST INTO ONE RADIAL OR 2 RADIALS - NO MATCH BOX

(1) 2 RADIALS, GROUNDED BASE, $e = 41$ db, $i = \frac{8.4\,mv}{47}$, E at sending end 20V p/p
R_r calculated $= .29\,\Omega$

(2) SINGLE RADIAL, GROUNDED BASE $e = 46$ db, $i = \frac{12.7\,mv}{47}$, R_r calculated $.38\,\Omega$

(3) SINGLE RADIAL, INSULATED BASE $e = 41$ db, $i = \frac{8\,mv}{47}$, R_r calc. $= .32\,\Omega$, $E = 35V_{p/p}$

$e = 35.4$ db, $i = \frac{4.4\,mv}{47}$, R_r calc $= .28\,\Omega$, $E\ 20V_{pp}$

(4) DOUBLE CONDUCTOR (2×.010), SINGLE RADIAL, INSULATED BASE
$e = 40$ db, $i = \frac{6.9\,mv}{47}$, $E = 20V_{p/p}$ R calc $= .32\,\Omega$

(5) DOUBLE CONDUCTORS, SINGLE RADIAL, GROUNDED BASE
$e = 46.8$ db, $i = \frac{13}{47}$, $E = 20V_{p/p}$ R calc $= .44\,\Omega$

$e = 46.5$, $i = \frac{12}{47} = .26\,A$, $E = 20V_{pp}$ R calc $= .46\,\Omega$

E_1 at transmission line output $= 28V_{p/p} = 10.0\,V_{rms}$ by oscilloscope measurement
i.e. input to antenna at feed

$$Z = \frac{E_1}{i} = \frac{10.0}{.26A} = |38.15|\,\Omega$$

Note that from impedance measurements on page 41 for the grounded base configuration at 10 MHz $= -j\,38.0 + 3.6\,\Omega$

The current measurement using the C.T. has thus been independently verified.

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tesenbr

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4/9/75 No testing today - Erection and assembly of 4-tower array consumed entire working day.
Weather: Clear, windy, 40-50°F.

4/10/75 Weather; clear, calm, 40-55°F

AM - Continued erection of 4-tower array on shielded table in field. Array is per diagram in proposal. Each antenna mast is grounded. Radials are insulated.

Impedance Measurements:

	F	Null	X	R Ω	X_i	Slope
	9 mHz	500	-j4800	1.05	-j22	12
	10 mHz	500	4900	1.25	-j10	
f_r	10.5 mHz	5000	5000	1.45	0	
	3.750	500	4480	.55	-j160	32
	5.15	5000	4450	.5	-j96	

150' SCALING

$X_C = \frac{120 + 10}{2} = j65\,\Omega$

$X_L = -j10 + j65 = j55$

$L = .876\,\mu H$

$C = 245\,pF$

$X_C = \frac{(3.75)32 + 160}{2} = j140$

$C = 113\,pF$

$X_L = -j160 + j140 = -j20 \approx 0$

SECURITY CLASSIFICATION (THIS PAGE)

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

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4-11-75 Weather, clear, calm 40-55°F

Impedance measurement with 4 tower-array installed on table top & bases grounded.

F	NULL	X	R	Xi	C/L
3.75	5000	4400	.4	-j 160	C
5.00	|	4450	.48	-j 110	|
7.00	|	4600	.5	-j 57	|
9.00	|	4800	.95	-j 22	|
10.00	|	4900	1.15	-j 10	|
10.50	5000	5000	1.4	0	C
12.00	0	215	1.75	+j 18	L
15.00	0	760	3.2	+j 51	|
20.00	0	2500	8.0	+j 125	|
23.00	500	4700	14.0	+j 183	L

Slope at 10 MHz = $\frac{40}{3}$ = 13.33

$X_C = -j\left(\frac{133+10}{2}\right) = -j71.5$, C = 223 pf

$X_L = +j71.5 - j10 = j61.5$, L = .97 μH

Same as above but signal is fed into opposing towers (E & W), N&S are open

F	NULL	X	R	Xi	C/L
3.75	5000	3950	.6	-j 280	C
5.00	|	4050	.6	-j 190	|
7.00	|	4300	.8	-j 100	|
9.00	|	4600	1.3	-j 44	|
10.00	5000	4800	1.6	-j 20	C
11.00	0	~~5050~~ 52	1.9	+j 5	L
12.00	0	315	2.4	+j 26	|
15.00	0	1800	4.4	+j 120	|
20.00	200	5000	11.5	+j 240	L

Slope at 10 MHz = 23.3

$X_C = -j\left(\frac{233+20}{2}\right) = -j126.5\ \Omega$ C = 126 pf

$X_L = j126.5 - j20 = j106.5\ \Omega$ L = 1.69 μH

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tisenbau

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4-11-75 data continued

SIGNAL INTO E & W DIAGONAL AND N & S SLANT ARE GROUNDED, BASES GROUNDED

f	NULL	X	R_i	X_i	C/L
3.15	5000	3950	.3	$-j280$	C
5.00	|	4050	.35	$-j190$	C
7.00	|	4300	.5	$-j100$	C
9.00	|	4600	1.1	$-j\ 44$	C
10.00	5000	4800	1.6	$-j\ 20$	C
11.00	0	52	1.5	$+j\ 5$	L
14.00	0	975	2.7	$+j\ 70$	L

Results are the same as previous run

SIGNAL INTO N & W (ADJACENT), E & S SLANT ARE GROUNDED, BASES GROUNDED

3.75	5000	3900	0	$-j293$	C
5.00	5000	4000	.3	$-j200$	C
7.00	5000	4250	.6	$-j107$	C
9.00	5000	4600	1.1	$-j\ 44$	C
10.00	5000	4780	1.7	$-j\ 22$	C
11.00	0	16	2.4	~~24~~ $+j\ 1$	L
14.00	0	975	3.4	~~24~~ $+j\ 70$	L

Average slope 22

$X_C = -j\dfrac{220+22}{2} = -j121$, $C = 131\,pF$

$X_L = j121 - j22 = j99$ $L = 1.57\,\mu H$

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

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4-14-75 WEATHER CLEAR, CALM, 35-50°F

RADIATION MEASUREMENTS - RADIATION AT 9.443 MHz 9:00 AM 1200 NOON
TECHNICIAN MEDICAL EXAM - 2:30 PM - NO AFTERNOON TESTING

RADIATION FROM 4-TOWER ARRAY, BASES GROUNDED. NORTH IS 0°.
ANTENNA FACTOR = 42 DB

AZIMUTH	e_{FS} dB	e_{FS} μV	i_{ANT}	$E_{ANT\ INPUT}$	dA	CALCULATED R_r Ω
60°	49.4	37	17.5 mv (.37A)	5Vp/p	300	.93
60°	50.8	~~44~~	17.5 mv	5Vpp	250	.91
60°	53.3	56			200	.95
90°	53.2	55				.91
120°	52.3	50				.75
150°	52.4	51				.78
180°	52.2	49				.72
210°	53.2	56				.91
240°	52.6	52				.81
270°	53.1	55				.91
300	53.3	56				.95
330	52.3	50				.75
360°	52.0	48				.69
30°	51.7	47	17.5 mv	5Vp/p	200	.67

$R_{av} = .82\ \Omega$

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 2 SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR MULTIPLE TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tozenber

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4-15-75 AM; CLOUDY, 40-50°F, CALM, RAIN LATE AFTERNOON

IMPEDANCE MEASUREMENTS

1. 4-TOWER ARRAY, BASE INSULATED, TOP GROUNDED

FREQUENCY (MHz)	NULL	X	R	X_i	C/L
3.75	5000	~~4850~~ 4360	0.60	$-j$ 171	C
5.00	|	~~4360~~ 4420	0.45	$-j$ 116	|
7.00	|	4550	0.70	$-j$ 64	|
9.00	|	~~4470~~ 4750	1.05	$-j$ 28	|
10.00	|	~~4750~~ 4850	1.40	$-j$ 15	|
11.00	5000	5020	1.75	$+j$ 2	C
14.00	0	525	2.85	$+j$ 31.5	L

Slope ~ 15

$$X_C = \frac{10 \times 15 + 15}{2} = 82.5$$

C = 193 pF

2. 4-TOWER-ARRAY BASE INSULATED, TOP GROUNDED, FEED E-W, GROUND INPUT TO N-S

FREQUENCY (MHz)	NULL	X	R	X_i	C/L
3.75	5000	3850	0.15	$-j$ 306	C
5.00	|	4000	0.30	$-j$ 200	|
7.00	|	4200	0.40	$-j$ 114	|
9.00	|	4550	1.10	$-j$ 50	|
10.00	|	4700	1.40	$-j$ 30	
11.00	5000	4950	1.60	$+j$ 5	C
14.00	0	850	3.30	$+j$ 61	L

Slope ~ 27.5

$$X_C = \frac{275 + 30}{2} \quad 152.5 \quad C = 104\,pF$$

3 3-TOWER ARRAY, BASE INSULATED, TOP GROUNDED, FEED E-W, GROUND INPUT TO N. SEE TABLE

FREQUENCY (MHz)	NULL	X	R	X_i	C/L
3.75	5000	3850	0.35	$-j$ 306	C
5.00	|	4000	0.75	$-j$ 200	|
7.00	|	4200	0.60	$-j$ 114	|
9.00	|	4500	1.10	$-j$ 56	|
10.00	|	4700	1.60	$-j$ 30	|
11.00	5000	4950	1.85	$-j$ 5	C
14.00	0	850	3.30	$+j$ 61	L

Slope ~ 25

$$X_C = \frac{250 + 30}{2} = 140, \quad C = \cancel{96\,pF}\ 114\,pF$$

SECURITY CLASSIFICATION (THIS PAGE)

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EQUIPMENT LOG FOR MULTIPLE TOWER STUDY
(Subsystem, Major Unit, Etc.)

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IMPEDANCE MEASUREMENT CONT'D 4-15-75

4. SAME AS (3) BUT TOWER BASE GROUNDED, TOP INSULATED.

f	NULL	X	R_2	X_1	C/L
3.75	5000	3950	0.55	$-j\,280$	C
5.00	|	4050	0.55	$-j\,110$	|
7.00	|	4250	0.60	$-j\,107$	|
9.00	|	4600	1.25	$-j\,44$	|
10.00		4750	1.65	$-j\,25$	|
11.00	5000	5020	1.85	$-j\,2$	C
11.00	0	37	1.75	$+j\,3$	L
14.00	0	950	2.55	$+j\,68$	L

... = 24

$\frac{-4\ ...}{4}$ = ...

5. 2-TOWER ARRAY (DIAGONAL) GROUNDED BASE, TOP INSULATED

f	NULL	X	R_2	X_1	C/L
3.75	5000	3900	0.45	$-j\,243$	C
5.00	|	4050	0.50	$-j\,190$	|
7.00	|	4250	0.75	$-j\,107$	|
9.00	|	4600	1.30	$-j\,44$	|
10.00		4800	1.60	$-j\,20$	|
11.00	5000	5000	1.90	0	C
14.00	0	940	.60	$+j\,67$	L
20.00	0	4700	11.0	$+j\,235$	L

slope ...

$X_C = \frac{-40}{2} = \ldots$

$X_L = 120 - 20 = 100$

$L = 1.59\,\mu H$.

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) E Toreaban

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY	ON	CUMULATIVE OPERATING TIME (4) STANDBY	ON

APRIL 16 1975 CALM, WARM, 50-60°F

MEASURE FIELDSTRENGTH WHILE RADIATING 9.993 MHz FROM DUAL ARRAY (½ of 4-TOWER ARRAY) FIRST FROM TABLE, THEN FROM GROUND LOCATION. TOWERS GROUNDED.

1. TABLE

$e =$ ~~46.8 dB~~ 50.2 dB, $I = \frac{11.3\,mV}{47}$ $d = 200\,ft$ $E = 30V_{p/p}$ measured via cable from amplifier.

Calculation: $R_r =$ ~~.57 Ω~~ 1.28 Ω

2. GROUND

$e = 46.8\,dB$, $i = \frac{11.3\,mV}{47}$, $d = 200\,ft$ $E = 30V_{p/p}$ measured on sending end of 110' line.

Calculation $R_r =$ ~~1.4 Ω~~ .57 Ω

APRIL 17 1975 CALM, WARM, 50-70°F

Repeat of April 16 measurement, but E is measured with scope probe at feed point (radial)

1/ TABLE

$e = 49.0\,dB$ $i = \frac{11.3\,mV}{47}$ $E = 8V_{p/p}$ Calculations $R_r = .9\,Ω$ $Z = 11.82\,Ω$

2/ GROUND

$e = 45.8\,dB$ $i = \frac{11.3\,mV}{47}$ $E = 10V_{p/p}$ Calculations $R_r = .45\,Ω$ $Z = 14.7\,Ω$

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(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tesenbe[illegible]

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APRIL 21 1975 WINDY, 40-50°F, SUNNY

RADIATING AT 999.3 mHz 4:30 AM TO 16:00

FIELD INTENSITY OF 2-TOWER ARRAY, BASES GROUNDED

d = 200'

ℓ db	I av	AZIMUTH	Rr calculated		E db abv 1μv	mV
46.2	11.4	0°	.48		88.3	26.01
47.2	11.5	315°	.57		89.2	28.84
45.8	11.3	270°	.45		87.9	24.83
47.8	11.5	225°	.66	.53Ω AV	89.8	30.90
46.8	11.5	180°	.52		88.8	27.54
46.9	11.1	135°	.57		88.9	27.86
46.5	11.3	90°	.50		88.6	26.92
46.4	11.2	45°	.51		88.5	26.61

Insulated bases

47.0	11.0	45°	.60	89.0	28.18
47.5	11.0	90°	.65	89.5	29.85
47.0	11.0	135	.60	89.0	28.18

Insulated base with 3rd tower EAST grounded input

46.0	11.0	90°	.49	88.1	25.41
45.8	10.8	135°	.48	87.9	24.83
45.2	10.8	180°	.42	87.3	23.17
46.8	10.8	225°	.59	88.8	27.54
44.8	10.8	270°	.38	86.9	22.14
48.0	10.7	315°	.80	90.0	31.62
46.8	10.9	0°	.58	88.8	27.54
45.9	11.0	45°	.48	88.0	25.12

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Rosenbaum

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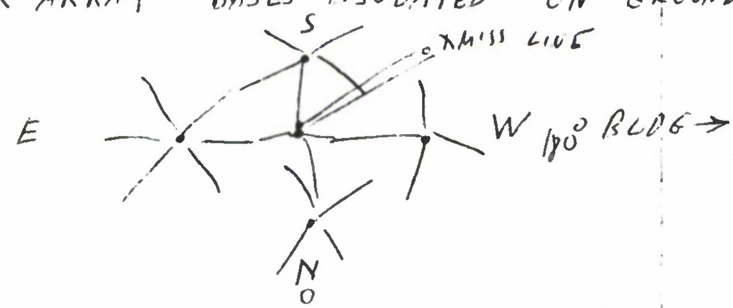
4-22-75 MOD. WINDY, CLEAR, 40-60°F

4-TOWER ARRAY BASES INSULATED ON GROUND. RADIATING AT 9.93 MHz



e_{db}	i_{AV}	E_{db} above 1μV	E mV	AZIMUTH	R_r calculated	d
49	11.5	90.9	35.08	90°	.48	150'
46	11.5	88.1	25.41	90°	.69	250'
47	11.5	89.0	28.18	90°	.55	200'
47.4	11.5	89.4	29.51	45°	.60	
46.8	11.5	88.8	27.54	135°	.52	
46.9	11.5	88.9	27.86	180°	.54 AV	
47.2	11.5	89.2	28.84	225°	.57	
46.5	11.6	88.6	26.92	270°	.49	
48.5	11.4	90.5	33.50	315°	.78	
47	11.4	89.0	28.18	0°	.56	200'

AV .58 Ω

Same configuration
Now radiating at 29.97 MHz

			3rd HARMONIC TEST		meter correction		E calibration 1μV	E mV
39.5	0.6	29.97 MHz	45°	11.87	×1.08	200'	78.0	7.94
41.0	0.375		45°	12.94 10.98	×1.08	100'	79.6	9.55
34.2	0.375		45°	13.10	×1.08	250'	72.4	4.17
38.9	0.6	29.97 MHz	45°	15.80	×1.08	250'	79.3	7.33
40.0	2.4	19.97 MHz	45°	2.34	×1.08	250	80.5	10.6
46.8	5.45		45°	2.25	×1.08	250	87.4	23.44
51.0	5.45		45°	2.66 3.71	×1.08	200	91.5	37.58
56.0	5.45		45°	2.80	×1.08	100	96.3	65.31
47.0	4.5	19.97 MHz	0°	2.22	×1.08	200	87.6	23.99

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(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S)

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4-23-75 Calm, clear, 50 - 65°F

RADIATING AT 9.93 MHz INTO 4-TOWER ARRAY

INPUT VOLTAGE MEASURED WITH OSCILLOSCOPE & PROBE BASES INSULATED : 12.5Vp/p

with $I = \frac{11.0}{47} = .234A$

BASES GROUNDED 6.4Vp/p with

$I = \frac{10.8}{47} = .230A$

PATTERN MEASUREMENT 4-TOWER ARRAY BASES GROUNDED, d=200'

e d/b	I, mV	E db above/µv	E mV	AZIMUTH	Rr calc.
45.5	10.9	87.6	23.99	0°	.44
45.3	11.3	87.4	23.44	45°	.39
45.2	10.9	87.3	23.17	90°	.41
44.6	10.9	86.7	21.63	135°	.36
44.9	10.9	87.0	22.39	180°	.38
45.5	10.9	87.6	23.99	225°	.44
44.6	10.9	86.7	21.63	270°	.36
46.0	10.9	88.1	25.41	315°	.50
45.0	10.6	87.1	22.65	45°	.49

$R_{r\,av} = .41\Omega$

On each tower 2 radials tied together to simulate only 11 radials

SHUT-DOWN MODE TEST E RW NOT FED, BUT BASE GNDED. NES FED, BASES INSULATED

44.8	11.5	87.0	22.39	0	.35
44.8	11.5	87.0	22.39	45	.35
45.0	11.5	87.2	22.91	90	.36
43.0	11.5	85.2	18.2	135	.23
42.8	11.5	85.0	17.78	180°	.22

200'

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ G Tezerdem

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4-23-75 continued

BRINGING TOWERS CLOSER TO EACH OTHER. INSULATED BASE

Measured at 135°, 200 ft

	e	i	e_{dt}
(1) NORMAL	46.8 db	11.5 mv	
(2) East 12" closer	47.0	11.5 mv	
(3) E & W - 12" closer	47.0	11.5 mv	
and E, W, N - 12" closer	47.0	11.5 mv	

No change noted.

Recheck of Single tower shunt fed, insulated base

e	e_{dt}	E	i	AZIMUTH	R_{calc}
41 db	89	28.18	110 mv	135°	.60 Ω

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tiezenbaum

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4-24-75 CLOUDY, 60-70°F, CALM
RAIN PM

TRANSMITTING AT 99.93 mHz INTO 4 ft base insulated tower antenna the 'standard' unit. All 200' distance

AZIM.	edb	I_{mv}	Edb above 1μv	E	Rr calc Ω
0°	48.2	11.2	90.2	32.36	.76
45°	50.1	11.1	92.0	39.81	1.17
90°	49.5	11.1	91.4	37.15	1.02
135°	48.5	11.1	90.5	33.50	0.83
180°	47.9	10.8	89.9	31.26	0.76
225°	49.2	10.8	91.2	36.31	1.03
270°	48.6	11.3	90.6	33.88	0.82
315°	49.8	11.3	91.7	38.46	1.06

Rav
.93Ω

INTO STD 3' ANTENNA

90°	40.5	6.85	82.5	13.34	.35Ω
135°	40.0 (20+20)	6.85	81.8	12.3	.29Ω

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER ______ SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR ______
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ M Tenenbaum

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4-25-75 , 60-70°F, HUMID, CALM

TRANSMITTING AT 99.93 MHz 11:00 to 15:45

1. 4-FOOT SLANT FED SINGLE ANTENNA INSULATED TOP & BOTTOM

AZIMUTH	db	I_{mv}	d	db above μv	E	R_{calc}	δ
0°	47.5	10.8	200	89.5	29.85	.69	
45°	48.2	10.8	200	90.2	32.36	.82	
90°	48.0	10.9	200	90.0	31.62	.77	R_{av} .73
135°	47.4	11.0	200	89.4	29.51	.66	
135°	47.6	11.0	200	89.6	30.20	.69	
135	50.0	11.0	150	91.9	39.35	.66	
135°	45.6	11.0	250	87.7	24.27	.69	

2. INSULATED BOTTOM ONLY OTHERWISE AS (1)

135°	47.2	11.2	200	89.2	28.84	.60

3. 4-FOOT SLANT FED SINGLE ANTENNA WITH 9 - 1.5FT RADIALS

45°	49.5	11.0	200	91.4	37.15	1.04		DOUBLE INSUL
90°	49.5	11.0	200	91.4	37.15	1.04		DOUBLE INSUL
135°	48.8	11.0	200	90.8	34.67	.91	.98	DOUBLE INSUL
135°	47.0	11.0	250'	89.0	28.18	.94		DOUBLE INSUL
45°	49.2	11.3	200	91.1	35.89	.92		SINGLE INSUL*
90°	49.1	11.3	200	91.0	35.48	.90	.87	"
135°	48.5	11.4	200'	90.5	33.50	.79	~~.434~~	"

* TOP BRASS

SECURITY CLASSIFICATION (THIS PAGE)

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EQUIPMENT LOG FOR MULTI-TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Tozenbu

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4-28-75 60-70°F, SUNNY

RADIATION AT 99.93 MHz 8:15 TO 15:45

FIELD STRENGTH MEASUREMENTS AT ≈ 200 FT. SINGLE SLANT FED ANTENNA

(1) INSULATION TOP & BOTTOM

Azimuth	e dB	I	d	e dB above 1 μv	E	R calc
45°	47.4 dB	10.8 mv	200 ft	89.4	24.51	.68

(2) INSULATION BOTTOM ONLY

45°	47.2 dB	10.7 mv	200 ft	89.2	28.84	.66	R av
0°	47.5 dB	10.6			89.5	29.85	.72	.63
90°	46.4 dB	10.6		88.9	27.86	.63	
135°	46.1 dB	10.6	200 ft	88.1	25.41	.52	
~~135~~							

(3) TWO-ANTENNA ARRAY - INSULATION BOTTOM ONLY (E AW)

135°	46.1	10.7	200 ft	88.1	25.41	.51	
135°	46.1	West Current 5.2	200	88.1	25.41	×	
135°	46.1	East Current 5.9	200	88.1	25.41	×	
	New Run						
135	47.2	11.4	200	89.2	28.84	.58	
180°	48.2	11.2		90.2	32.36	.76	
225	48.7	11.2		90.7	34.28	.85	
270	48.2	11.2		90.2	32.36	.76	
315	48.4	11.2		90.9	35.08	.89	R av
0	48.0	11.2		90.0	31.62	.73	.76
45	48.4	11.5		90.4	33.11	.76	
90°	48.2	11.4	200	90.2	32.36	.73	

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ G Peterson

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4-28-75 cont'd

(4) TWO ANTENNA ARRAY - TOP & BOTTOM IS INSULATED E & W

AZM	Edb	I	d	Edb adjusted	Emv	Rcalc
0°	47.7	10.9	200	89.7	30.55	.71
45°	49.0	10.9		91.0	35.48	.96
90°	48.9	11.0		90.9	35.09	.93
135°	47.7	11.0		89.7	30.55	.70
180°	48.6	10.8		90.6	33.88	.89
225°	48.8	10.8		90.8	34.67	.94
270°	48.2	10.9		90.2	31.49	.78
315°	49.5	10.9	200	91.4	37.15	1.05

/Rav = .87

INDUCTION TESTS: TWO ANTENNA ARRAY, INSULATED BASE, TOP NOT INSULATED. FEEDING EAST ANTENNA ONLY, WEST IS LEFT OPEN.

CURRENT FLOW INTO EAST SLANT WIRE $\frac{36\,mv}{47}$ = .77 Amperes

CURRENT MEASURED IN TOWER, GROUNDED OR UNGROUNDED, OF WEST ANTENNA = $\frac{.97\,mv}{47}$ = .021 A   db: $\frac{.77}{.021}$ = 36 or 31.3 db

AT 135° 200' E = 56.5 db   R calc = .86

VOLTAGE MEASUREMENTS WITH BALLANTINE METER INPUT NOT TERMINATED:

INPUT TO EAST; 40 Vrms
AT ONE RADIAL INSULATOR OF WEST; 26 Vrms
AT ROD OF WEST 20 Vrms

ALL VOLTAGES WR TO GND.

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EQUIPMENT LOG FOR MULTITOWER STUDY (Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tesenbaum

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4-29-75 CLOUDY, 45-55°F, WINDY

RADIATING AT 9.993 mHz 9:00 TO 15:45

Recheck of grounded base operation for 2 antenna array (E & W)

135° 44.9 db 11.2 mv 87.1 db 22.65 mv Rcal: .37Ω

Repeat above with 3rd antenna erected but not energized.

135° 45.4 db 11.2 mv 87.5 db 23.71 mv Rcal ≅ .41Ω

(compare with data pg 7. for 135°)

Removed ground, i.e. double insulation

135° 47.4 db 10.4 89.4 24.51m Rcalc = .73Ω

(compare with data pg 14 for 135°)

Induction Measurements

1. Dual antenna, grounded rods, E & W. Measurements on ungrounded and double insulated 3rd North antenna

VOLTAGE MEASUREMENT, SCOPE PROBE:

VIN E&W: 21 Vp/p

E RADIAL AT INSULATORS (LOWER)

15°	RADIAL	20 Vp/p	E1
45°		22 Vp/p	E2
75°		23 Vp/p	E3
105°		22 Vp/p	E4
225°		21 Vp/p	E6
255°		23 Vp/p	E7
285°		23 Vp/p	
345°		20 Vp/p	
165°		22 Vp/p	E5

VOLTAGE AT ROD: 13 Vp/p

ANTENNA CURRENT 24 mV

FIELD STRENGTH @ 135° 53 db

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4-29-75 cont'd

INDUCTION MEASUREMENT, DUAL ANTENNA, GROUNDED ROD, $\frac{48\,mV}{IA}$ CURRENT
FIELD STRENGTH 56.8 db

CURRENT TRANSFORMER MEASUREMENT, EACH RADIAL ON N

15° = .60mV I_1 INPUT TO E/W ; 35 Vp/p
75° = .70mV I_2 VOLTAGE ON RADIAL 180° : 33 Vp/p
255° = .60mV I_3 75° : 44 Vp/p
315° = .65mV I_4 45° : 44 Vp/p
ROD : 22 Vp/p

FEED TWO DOUBLE INSULATED (E/W) TOWERS
MEASURE VOLTAGES & CURRENTS ON NORTH

CURRENT INTO E/W : 60mV
INPUT VOLTAGE ; 75Vp/p

RADIAL: 15° E = 50Vp/p
45°
75° I = 1mV
105°
345° 50Vp/p I = 1mV
ROD — .4mV

WITH METAL TOP LOADING 0.4mV

WITH METAL TOP LOADING & GROUNDED ROD 0.9mV

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4-30-75 50-60°F, CLEAR, CALM

AM. REPAIR OF TOP LOADING ASSEMBLIES, FABRICATION OF ONE TOP LOADING ASSEMBLY WHICH HAS A #41 LEAD-IN RADIAL (DIA .00275)

PM: IMPEDANCE MEASUREMENTS - SINGLE, SLANT-FED, #41 LEAD IN, BASE GROUNDED, TOP INS

F (MHz)	NULL (Ω)	X	R (Ω)	X_i	C/L
4	5000	2900	6.4	-j525	C
6	5000	3400	6.9	-j267	C
8	5000	4100	8.2	-j112.5	C
9	5000	4500	9.4	-j55	C
10	5000	5000	10.5	0	C
11	0	550	11.6	+j50	L
15	0	4200	21.5	+j280	L

Slope = 50

$X_C = \frac{10(50)}{2} = 250\Omega$

C = 63.7 pF

L = 3.98 μH

5-1-75 AM 50-60°F, CLOUDY, CALM
PM RAIN

REPEAT OF ABOVE BUT BASE IS INSULATED

F	NULL	X	R	X_i	C/L
4	5000	2700	5.8	-j575	C
6	5000	3050	6.4	-j325	C
8	5000	3750	7.5	-j156	C
9	5000	4150	6.3	-j94	C
10	5000	4600	9.8	-j40	C
11	0	160	11.2	+j15	L
15	0	3500	22	+j233	L
16	0	4800	28.5	+j300	L
10	5000	5000	10.2	0	C

GROUNDED BASE, RECHECK

Slope = 55

$X_C = \frac{550+40}{2} = -j295$

C = 54 pF

$X_L = 295 - 40 = +j255$

L = 4.06 μH

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ____________ G. Overbu

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY	TYPE OF OPERATION (3) ON	CUMULATIVE OPERATING TIME (4) STANDBY	CUMULATIVE OPERATING TIME (4) ON

5/1/X CONTINUED

EXTENSION OF BRIDGE RANGE WITH 100pF CAPACITOR PARALLELING ANTENNA DURING MEASUREMENT

f (KHz)	NULL	X	R	X_i	C/L	X_i actual*	Remarks	
16	5000	3300	0	-j106	C	+j260	CAP ONLY	
16	5000	2150	7.9	-j178	C		CAP +ANT	
20	5000	3350	0	-j82.5		+j472	CAP ONLY	
20		3000	.6	-j100			CAP +ANT	
25		3650	.6	-j54		+j297	CAP ONLY	POOR
25		3350	0	-j66			CAP + ANT	NULL
30		4200	0	-j27		+j27	CAP ONLY	POOR
30	5000	4200	0	-j27	C		CAP +ANT	NULL

*see TYPE 916A INSTRUCTION MANUAL, PG 7 FOR FORMULAS

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) [signature]

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-2-75 RAINING

CHECKED CALIBRATION OF BALLANTINE RMS METER AT 20 & 30 MHZ TO PROPERLY EVALUATE HARMONIC MEASUREMENTS. USED CALIBRATED 585/82 TEKTR. OSCILLOSCOPE.

SCOPE VOLTAGE V P/P	RMS METER Vrms	FREQUENCY MHz
2.7	100 mV	10
2.6	100 mV	20
2.7	100 mVS	30

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Rosenbaum

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-5-75 CLOUDY, 50-60°F, CALM

INSTALLED A COMPLETE TOP LOADING ARRAY FOR ONE TOWER, MADE WITH 41 AWG RADIALS. NO SWIVELS, FINE WIRES IS TAPED TO SLEEVING. IMPEDANCE MEASUREMENT OF SLANT FED 41 ANTENNA ROD TOP INSULATED, ROD BOTTOM GROUNDED.

f	NULL	X	R_n	X_i	C/L	REMARKS
4	5000	2620	8.8	-j595	C	
6	5000	3040	7.5	-j327		
8	5000	3650	8.4	-j168		
9	5000	4100	4.2	-j100		
10	5000	4550	10.0	-j45		
11	5000	5000	11.2	0	C	
13	0	1370	14.7	+j105	L	
15	0	3350	20.1	+j223	L	
20	5000	3400	0	-j80	C	100PF CAP ONLY } +j400
20	5000	3000	0.4	-j100	C	100PF CAP + ANT
25	5000	1860	0.3	-j126	C	47PF CAP ONLY } j1008
25	5000	1400	0	-j148	C	47PF CAP + ANT
27	5000	1950	0	-j113	C	47PF CAP ONLY } +j1909
27	5000	1720	0	-j121	C	47PF CAP + ANT
30	5000	2100	0	-j97	C	47PF CAPONLY } +j3233
30	5000	2000	0	-j100	C	47PF + ANT

Slope = 50

$X_C = \frac{10(50)+45}{2} = -j272.5$

C = 58pF

$X_L = +j272.5 + j45 = j227.5$

L = 3.62 mH

RANGE EXTENSION OF BRIDGE // CAP X_a

$$X_x = \frac{-X_a\left[R_e^2 + X_e(X_e - X_a)\right]}{R_e^2 + (X_e - X_a)^2}$$

if $R_e \approx 0$ $\quad X_x = \frac{-X_a X_e}{X_e - X_a}$

see pg 21 for CONTINUATION

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tesebr

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5/5/75 CONTINUED

TEST REPEATED WITH BASE OF ROD INSULATED. ROD IS ~~[illegible]~~ DOUBLE INSULATED NOW

f	NULL	X	R Ω	Xi		C/L	
4	5000	2250	7.9	−j688		C	Slope = 51
6	5000	2780	7.8	−j370		C	$X_C = \frac{510+80}{2} = -j295\Omega$
8	5000	3350	8.4	−j206		C	
9	5000	3770	9.0	−j137		C	C = 54pF
10	5000	4200	10.0	−j80		C	L = 3.42μH
11	5000	4620	11.0	−j35		C	
13	0	920	14.5	+j70		L	
15	0	2630	20.0	+j175		L	
18	5000	3300	0	−j94	+j320	C	100pF CAP ONLY
18	5000	2600	2.6	−j133		C	100pF + ANT
23	5000	3500	0	−j65	+j390	C	100pF CAP ONLY
23	5000	3200	.9	−j78		C	100pF + ANT
25	5000	1860	0.3	−j126	j841	C	47PF CAP ONLY
25	5000	1300	0	−j148		C	47PF & ANT
27	5000	1950	0	−j113	j1309	C	47PF CAP ONLY
27	5000	1680	0	−j123		C	47PF + ANT
30	5000	2100	0	−97	j3233	C	47 PF CAP ONLY
30	5000	2000	0	−j100		C	47PF + ANT

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDIES
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tesinben

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-6-75 CLOUDY 50-65°

RADIATION AT 9.993 MHz STARTING 12:00
FIELD INTENSITY OF 4 TOWER ARRAY, TOP AND BOTTOM INSULATED

AZIMUTH	DB	I mv	d	Edb above 1 mv	E mv	Rr calc	
0°	47.7	11.3	200	89.7	30.55	.67	
45	48.0	11.3		90.0	31.62	.71	
90	48.1	11.3		90.1	31.99	.73	R AV = .70
135	47.2	11.3		89.2	28.84	.59	
180	47.8	11.5		89.8	30.90	.66	
225	48.9	11.3		90.9	35.08	.88	
270	46.2	11.3		88.3	26.01	.48	
315	48.8	11.3	200	90.8	34.67	.86	
135	47.6	11.5	200	89.6	30.20	.65	
135	45.5	11.5	250	87.5	23.75	.61	
135	43.5	11.5	300	85.7	19.28	.57	

HARMONIC MEASUREMENTS 19.993 MHz

135	58.0	11.0×1.08	200	97.9	78.52	3.98	
135	56.0	11.0×1.08	250	95.2	57.54	3.34	Rav = 3.6
135	54.0	11.0×1.08 (11.88)	300	93.8	48.98	3.48	

HARMONIC MEASUREMENTS AT 29.993 MHz

135	50.5	2.5×1.16	200	88.8	27.54	8.22	Av 8.26
135	48.6	2.5×1.16	250	86.9	22.14	8.29	
135	48.6	2.5×1.16	300	86.9	22.14	11.92	

"2.9

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 2 SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ G. Trinkle

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	TYPE OF OPERATION (3) ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	CUMULATIVE OPERATING TIME (4) ON
5-7-75 WARM, SUNNY, CALM					
RADIATION AT 9.993 MHz 10:00					
4 TOWER ARRAY - DOUBLE INSULATION OF TOWER, FIELD STRENGTH:					
135° 11mV 47.2 db 200'					
INPUT VOLTAGE WITH MAN INSIDE ARRAY TO READ OSCILLOSCOPE					
15 Vp/p Current 12-12.5 mV					
At sending end Voltage = 28 Vp/p					
Removed extraneous ground leads in array floor.					
135° 10.5 mV 47.0 db 200'					

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Rosenbaum

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-8-75 WARM, SUNNY, CALM

IMPEDANCE MEASUREMENT 2-ANTENNA ARRAY - DIAGONAL, TOP AND BOTTOM OF TOWER INSULATED

f	NULL	X	R	X_i		C/L	
4	5000	3850	0.6	-j288		C	SLOPE = $\frac{56}{2}$ = 27.5
6		4050	1.1	-j158			$X_C = \frac{275+25}{2} = 150$
8		4350	1.6	-j81			C = 106pF
9		4500	2.0	-j56			
10		4750	2.4	-j25			
11	5000	5000	2.9	0		C	
12	0	220	4.2	+j18		L	
14	0	850	4.9	+j61		L	
16	0	1750	7.9	+j109		L	
20	0	4800	15.5	+j240		L	
25	5000	3500	0	-j60	+j360	C	100pF CAP ONLY
25		3200		-j72			100pF CAP + ANT
25		1700		-j132	+j390		47pF CAP ONLY
25		0		-j200			47pF + ANT
27		1850		-j117	+j486		47pF CAP ONLY
27		850		-j154			47pF + ANT
30		2400		-j87	+j465		47pF CAP ONLY
30		1800	0	-j107			47pF + ANT
Repeat 11	5000	4900	2.8	-j9		C	

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Ditzenberger

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-9-75 WARM, CLEAR, CALM

IMPEDANCE MEASUREMENT DUAL ANTENNA- DOUBLE INSULATION
HIGH FREQUENCY POINTS

f	NULL	X	R	X_i/X_e	C/L	X_i	REMARKS
16	0	1100	7	+106	L		
17	0	2250	6.8	+132	L		
18	0	3100	4.5	+172	L		
19	0	4200	6.4	+221	L		
20	0	4900	14.5	+245	L		
22	5000	3300	0	−77	C	+262	47pF CAP
22		2600		−109			47pF CAP +ANT
24		3600		−58		+218	47pF CAP
24		3100		−79			47pF CAP +ANT
26		3750		−48		+j240	47pF CAP
26	5000	3450	0	−60	C		47pF CAP +ANT
27	5000	1750	0	−120	C	+j454	47pF CAP
27	5000	600	0	−163	C		47pF CAP +ANT
30	5000	1900	0	−103	C	+721	47pF CAP
30	5000	1400	0	−120	C		47pF CAP +ANT
30	5000	2000	0	−100	C	+766	47pF CAP
30	5000	1550	0	−115	C		47pF CAP +ANT
32		750	0	−133	C	+902	27pF CAP
32		0	0	−156			27pF +ANT
35		1400	0	−103		+1429	27pF
35		1100	0	−111			27pF + ANT
40		2000	0	−75		−487	27pF
40		2400	0	−65			27pF +ANT
42.5		3400	0	−38		−58	27pF
42.5	5000	4000	0	−23	C		27pF +ANT

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTITOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S)

G. Tiselbaum

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-12-75 WARM, CLEAR, WINDY

IMPEDANCE MEASUREMENT - 4 TOWER ANTENNA - INSULATION TOP AND BOTTOM OF ROD

f	NULL	X	R	Xi	C/L		Remarks
	~~5000~~						
4	5000	4380	0.70	$-j155$	C		
6	5000	4450	0.85	$-j92$	C		
8	5000	4600	1.3	$-j50$	C		
9	5000	4700	1.6	$-j33$	C		
10	5000	4850	2.0	$-j15$	C		
11	~~5000~~	20	2.2	$+j2$	L		
12	0	150	4.6	$+j13$	L		
14	0	560	3.8	$+j40$	L		
16	0	1050	5.6	$+j58$	L		
18	0	1650	7.6	$+j92$	L		
20	0	2420	6.1	$+j121$	L		
22	0	3900	17.0	$+j177$	L		
24	5000	3500	0	$-j63$	C	100pF CAP	
24	5000	2400	0.4	$-j108$	C	100pF + ANT	
28	5000	1980	0	$-j108$	C	47pF CAP	$+j274$
28	5000	0	0	$-j178$	C	47pF CAP + ANT	
30	5000	2100	0	$-j97$	C	27pF CAP	$+j285$
30	5000	680	1.2	$-j147$	C	27pF CAP + ANT	
32	5000	2400	0	$-j81$	C	47pF CAP	$+j240$
32	5000	1350	0	$-j114$	C	47pF CAP + ANT	
34	5000	2700	0	$-j68$	C	47pF CAP	$+j278$
34	5000	1950	0	$-j90$	C	47pF CAP + ANT	
36	5000	~~3200~~ 3000	0	$-j56$	C	47pF CAP	j ~~215~~ 448
36	5000	~~2650~~ 2700	0	$-j64$	C	47pF CAP + ANT	
38	5000	1750	0	$-j85$	C	27pF CAP	$j741$
38	5000	1350	0	$-j96$	C	27pF CAP + ANT	

Slope at 10 MHz

$$X_C = \frac{175+15}{2} = \frac{190}{2} = 95$$

$C = 168\,pF$

$X_L = 95 - 15 = 80$

$L = 127\,\mu H$

Recalculation in H slope = 17

$X_C = \frac{185}{2} = 92.5$ $C = 172\,pF$

$X_L = 77.5$ $L = 123\,\mu H$

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 2 SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______ B. Dezenbu

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY	TYPE OF OPERATION (3) ON	CUMULATIVE OPERATING TIME (4) STANDBY	CUMULATIVE OPERATING TIME (4) ON

5-12-75 continued

F	NULL	X	R	Xi	C/L			
35	5000	2800	0	-63	C		47pF CAP	+j311
35		2250	0	-j'79	C		47pF + ANT	
37		3200	0	-j'49	C		47pF CAP	+j315
37	5000	2850	0	-j'58	C		47pF + ANT	
37	5000	950	0	-j'109	C		27pF CAP	j808
37	5000	340	0	-126	C		27pF + ANT	
39		2100	0	-j74		+j1443	27PF CAP	
39		1950	0	-j78			27PF + ANT	
40		2600	0	-j'60		-j'660	27PF CAP	
40		2800	0	-j'55			27PF + ANT	
41		2000	0	-j'73		-j'460	27 PF CAP	
41		2400	0	-j'63			27PF + ANT	
42		2400	0	-j63		-j297	27 PF CAP	
42	5000	2800	0	-j'52	C		27PF + ANT	

SECURITY CLASSIFICATION (THIS PAGE)

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G Tonerban

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5-13-75 WARM 60-75°, CLOUDY, CALM

IMPEDANCE MEASUREMENT 4-TOWER ARRAY INSULATED TOP & BOTTOM, ANTENNAS SEPARATED FROM NORMAL ~~xxx~~ SLANT FEED POINT BY ~~xx~~ 2 FEET, TOTAL DIAMETER OF 4 TOWER CIRCLE IS (4.5)(2) + (6.5)(2) = 22 FT

f	NULL	X	R	X_i	C/L
9	5000	4900	2.2	-j11	C
10	0	76	2.8	+7.6	L
11	0	190	2.8	+17	L

Slope $\frac{28}{2} = 14$

$X_C = \frac{140 + 7.6}{2} = \cancel{xxx}\ 66.2$

$C = 240pF$, $X_L = \cancel{74}\ 7.6 + 66.2\ \cancel{xxx}$
73.8 $\cancel{xx}$

$L = 1.175\ \mu H$

ANTENNAS WERE MOVED CLOSER BY 1 FOOT V-DIA IS NOW 20'.

4	5000	4400	0.8	-j150	C
6	5000	4550	0.6	-j75	C
8	5000	4100	1.3	-j38	C
9	5000	4830	1.7	-j19	C
10	5000	4980	2.0	-j2	C
11	0	145	4.5	+j13	L
12	0	255	3.1	+j21	L
14	0	750	5.0	+j54	L
16	0	1300	7.1	+j81	L
20	0	3300	15	+j165	L
22	0	5000	26.5	+227	L

Slope = $\frac{32}{2} = 16$

$X_C = \frac{162}{2} = 81$ $C = 197pF$

$X_L = 81 - 2 = 79$ $L = 1.26\ \mu H$

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EQUIPMENT LOG FOR MULTI TOWER STUDY
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S)

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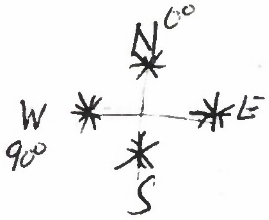
5/14/15 SUNNY, WARM -75°F, CALM

RADIATING AT 9.993 MHz FROM GROUND POSITION. RODS INSULATED TOP & BOTTOM - 22 FT DIAMETER - 2 FT FROM FEEDPOINT IS LOCATION OF ANTENNA



AZIMUTH	DB	I mv	d	Edb above 1mv	E mv	Rr calc
0°	48.1	11.0mV	200	90.1	31.99	.77
45°	48.6			90.6	33.88	.87
90°	48.1			90.1	31.99	.77
135°	47.6 ~~49.0~~			89.6	30.20	.69
180°	49.0			91.0	35.48	.95
225°	49.2			91.2	36.31	.99
270°	47.8			89.8	30.90	.72
315°	49.0			91.0	35.48	.95
157½°	48.3	11.0mV	200	90.3	32.73	.81

.84 average

SECOND & THIRD HARMONIC READINGS WITH SAME SETUP

135	55.2	8.2	200
180	55.2	8.2	200
225	54.8	8.2	200

19.993 MHz

135	39.2	1.55	200
180	39.3		200
225	39.3		200
225	41.2		150
225	38.6		250
225	37.1		263

SECURITY CLASSIFICATION (THIS PAGE) ______

LOG NUMBER 2 SYSTEM SERIAL NUMBER ______

EQUIPMENT LOG FOR MULTI TOWER STUDIES
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ______

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5/15/75 REWORKING 4' MODELS TO 1.5' MODELS

5/16/75 Reworking 4' Models to 1.5' Models

5/19/75 IMPEDANCE MEASUREMENT FOR 150' MODEL SCALED IN 1.5/4 RATIO FROM 4' MODEL EXCEPT FOR TOP LOADING ELEMENTS - SINGLE SLANT FED ANTENNA, DOUBLE INSULATED

F	NULL	X	X_i	R_i	
9	5000	495	$-j501$	0	C
10	5000	625	$-j438$	0	C
11	5000	700	$-j391$	0	C

Slope $= \frac{110}{2} = 55$

$X_C = \frac{550+438}{2} = 494$, $C = 32\,pF$

$X_L = 56$, $L = .89\,\mu H$

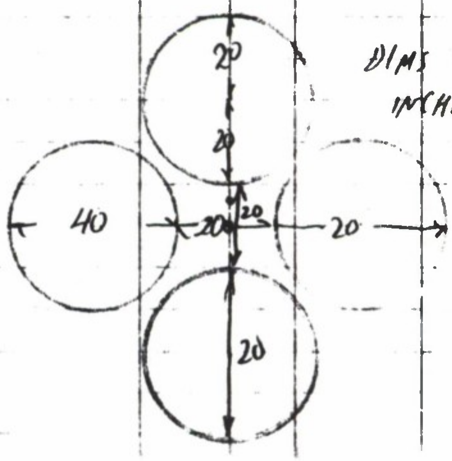
5/20/75 4-ANTENNA ARRAY; 1 1/2 ft MODELS, DOUBLE INSULATED. SEPARATION 9" ADDITIONAL PER ANTENNA

4	5000	3400	$-j400$	0	C
6		3500	$-j250$	0	
8		3580	$-j177$	0	
9		3650	$-j150$	0	
10		3700	$-j130$	0	
11		3750	$-j114$	0	
12		3820	$-j98$	0	
14		3950	$-j75$	0	
16		4100	$-j56$	.2	
18		4300	$-j39$	1.0	
20		4500	$-j25$	1.2	
22	5000	4850	$-j7$	2.1	C
24	0	840	$+j35$	3.0	L
26	0	1350	$+j52$	2.4	L

Slope = 18

$X_C = \frac{180+130}{2} = 155$ $C = 103\,pF$

$X_L = 155 - 130 = 25$ $L = .39\,\mu H$



DIMS IN INCHES

SECURITY CLASSIFICATION (THIS PAGE)

LOG NUMBER 2 SYSTEM SERIAL NUMBER

EQUIPMENT LOG FOR MULTI TOWER STUDIES
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) G. Teselan

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3) STANDBY ✓	ON ✓	CUMULATIVE OPERATING TIME (4) STANDBY	ON

5-21-75 HOT, WINDY, CLEAR

ASSEMBLED 4 - 1.5FT ANTENNAS ON GROUND FOR RADIATION TEST, RADIATED AT 9.993MHz 13:00-15:30 - ARRAY PATTERN AS ON PAGE 30

RESULT.

AZIM	λ	Ecal	Emv/m	Rcalc	d
180°	11.2mv	81	11.22	.09Ω	200'

5/22/75 CIRCULAR MEASUREMENT FOR ABOVE CONFIGURATION - RADIATION AT 9.993 MHz 9:00 TO 12:00 AM

0	11.2mv	81.5	11.89	.103
45		81.2	11.48	.096
90		80.5	10.59	.082
185		80.6	10.72	.084
180		80.2	10.23	.076
225		81.4	11.75	.100
270		81.6	12.02	.105
315	11.2mv	82.1	12.74	.118

Rav = .0955
≡ .096
≃ .1

VOLTAGE MEASUREMENTS Vp/p SCOPE INPUT: 30Vp/p TOWER BOTTOM: 40Vp/p
TOP: 110Vp/p RADIAL END 110Vp/p

SECURITY CLASSIFICATION (THIS PAGE) ____

LOG NUMBER 2 SYSTEM SERIAL NUMBER ____

EQUIPMENT LOG FOR MULTI TOWER STUDYES
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER(S) ____ G. [signature]

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5/22/75 WARM, WINDY

REPEAT OF 1.5FT RADIATION TEST BUT TOPS OF ROD ARE CONDUCTING - RADIATING AT 9.993 MHz 0900 - 15:30

AZIMUTH deg	i mV	E db mV/m	E db 81	E mV	R calc Ω	d
0	11.2	39.2	80.0	11.22	.092	200
45			38.9	80.3	10.35	.078	
90			38.5	80.1	10.12	.074	
135			37.9	79.5	9.44	.065	
180			38.4	80.0	10.0	.073	
225			39.9	81.7	12.16	.108	
270			39.5	81.3	11.62	.098	
315	11.2	40.0	81.8	12.30	.110	200
135	11.2	40.0	81.8	12.30	.062	150
135	11.2	35.9	77.9	7.85	.070	250

$R_{AV} = .087\Omega$

LIST OF SYMBOLS

X_i	Input reactance of antenna	ohms
X_{C_a}	Antenna capacitive reactance	ohms
X_{L_a}	Antenna inductive reactance	ohms
R_i	Input resistance of antenna	ohms
R_r	Radiation resistance of antenna	ohms
R_T	Total antenna resistance	ohms
R_L	Antenna loss resistance	ohms
E	Field intensity	μv/meter
Δf	Intrinsic bandwidth, efficiency bandwidth product	kHz
d	Distance from antenna to field intensity measuring point	miles
I_a	RMS antenna current	amperes
P	Power	watts
f	Frequency	Hz
f_{sr}	Series resonant frequency	Hz
f_o	Center frequency	Hz
C_a	Antenna capacitance	farad
L_a	Antenna inductance	henry
L_T	Transmitter output inductance	henry
E_{TH}	Top hat voltage	volts
E_i	Antenna input voltage	volts
η_A	Radiation efficiency	

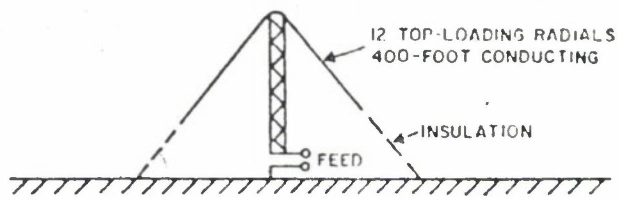


Figure 1. Present Single-Tower Antenna, Elevation View

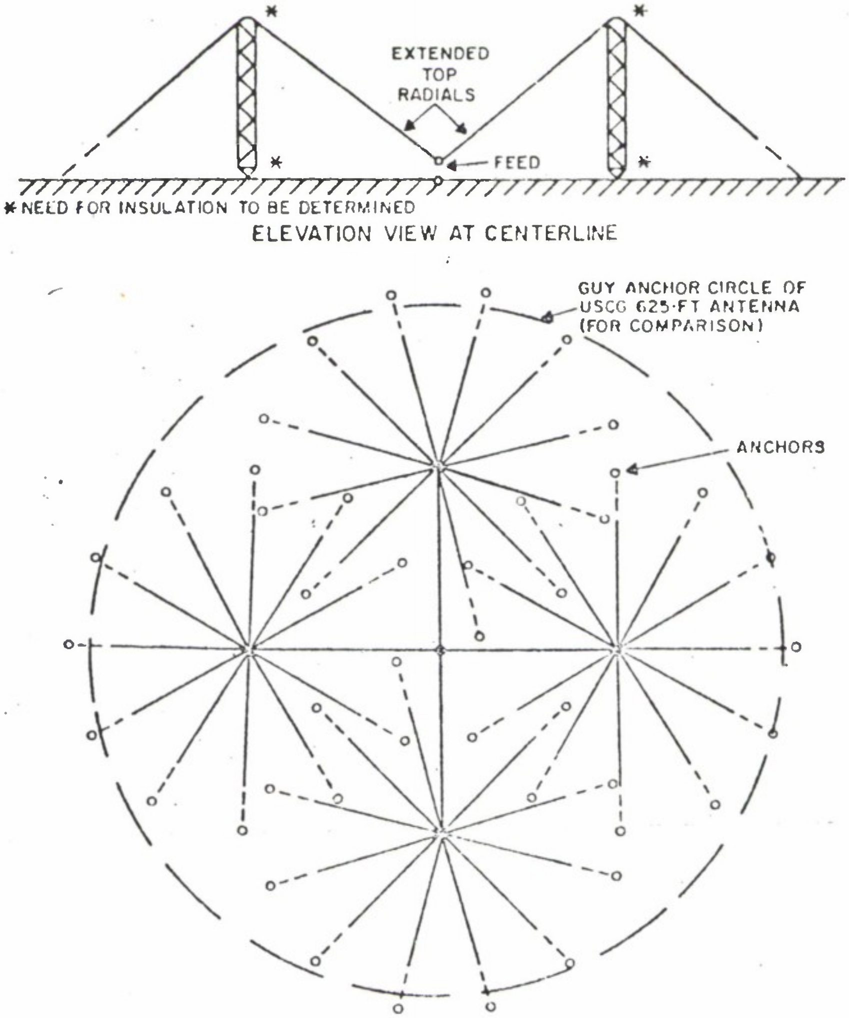
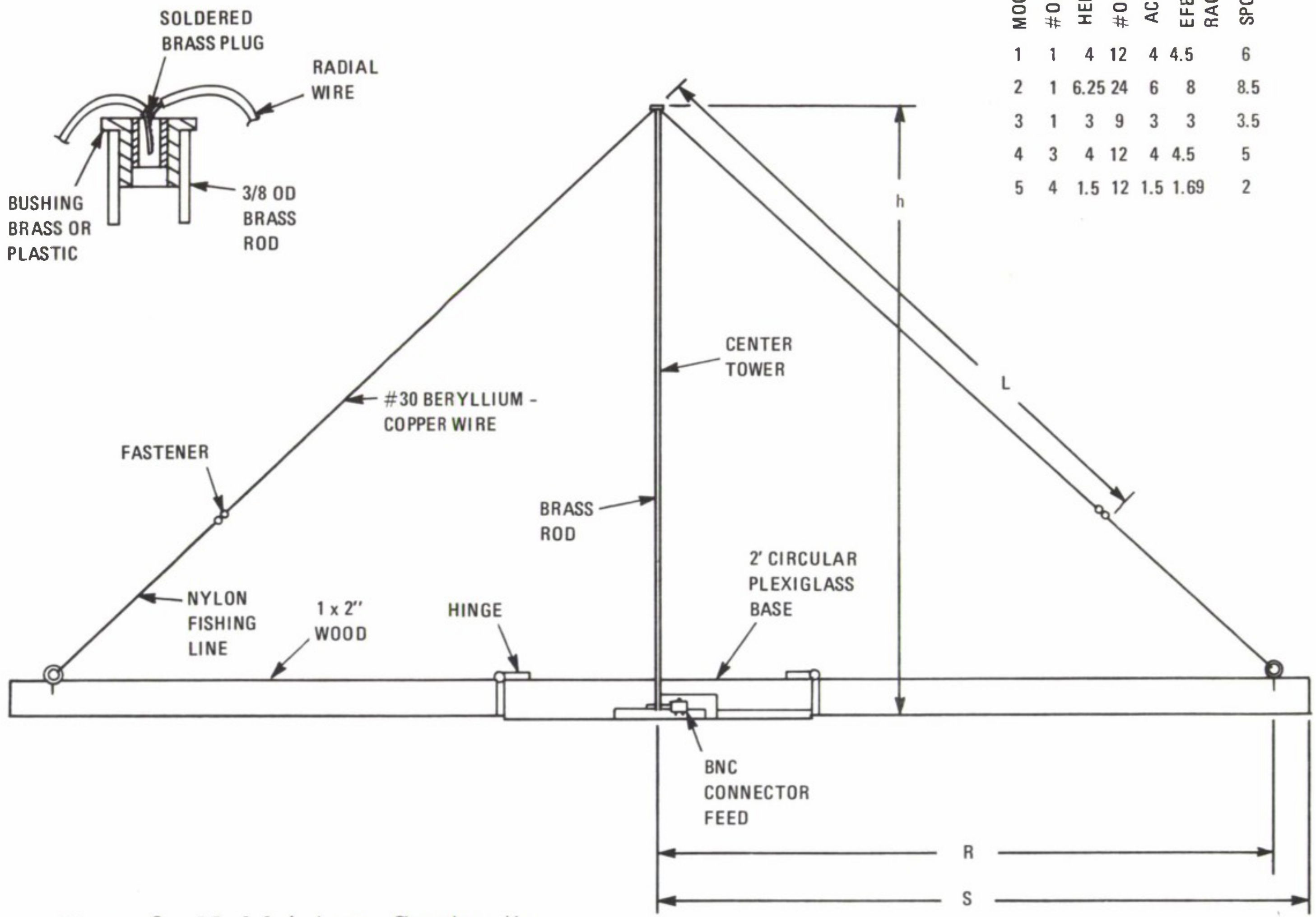


Figure 2. 400-foot, 4-Tower Antenna Array



MODEL S/N	# OF MODELS	HEIGHT - h	# OF SPARES - N	ACTIVE LENGTH - L	EFFECTIVE GROUND RADIUS - R	SPOKE LENGTH - S
1	1	4	12	4	4.5	6
2	1	6.25	24	6	8	8.5
3	1	3	9	3	3	3.5
4	3	4	12	4	4.5	5
5	4	1.5	12	1.5	1.69	2

Figure 3. Model Antenna Construction

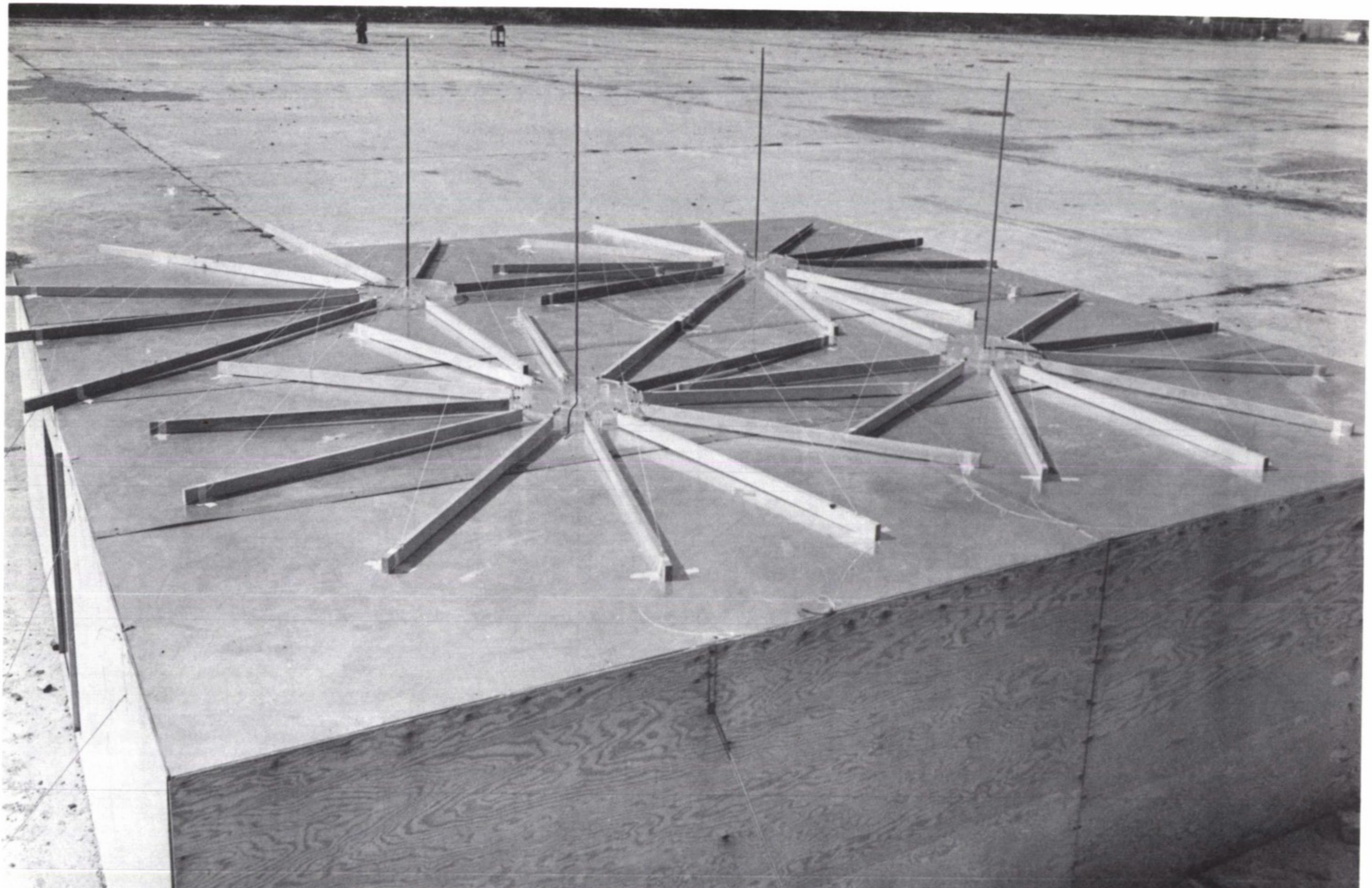


Figure 4. Photograph of 4-Tower Array Model

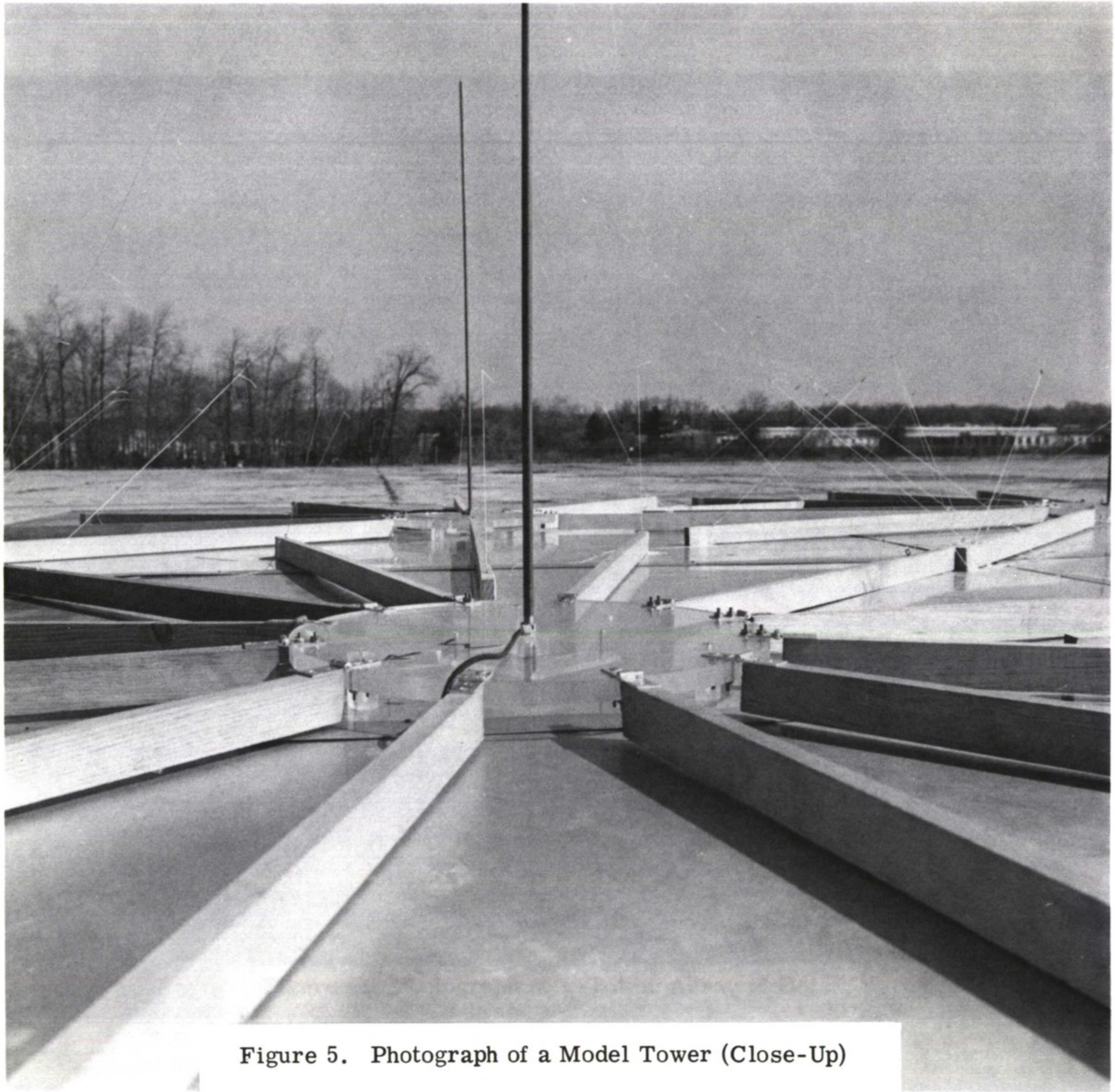


Figure 5. Photograph of a Model Tower (Close-Up)

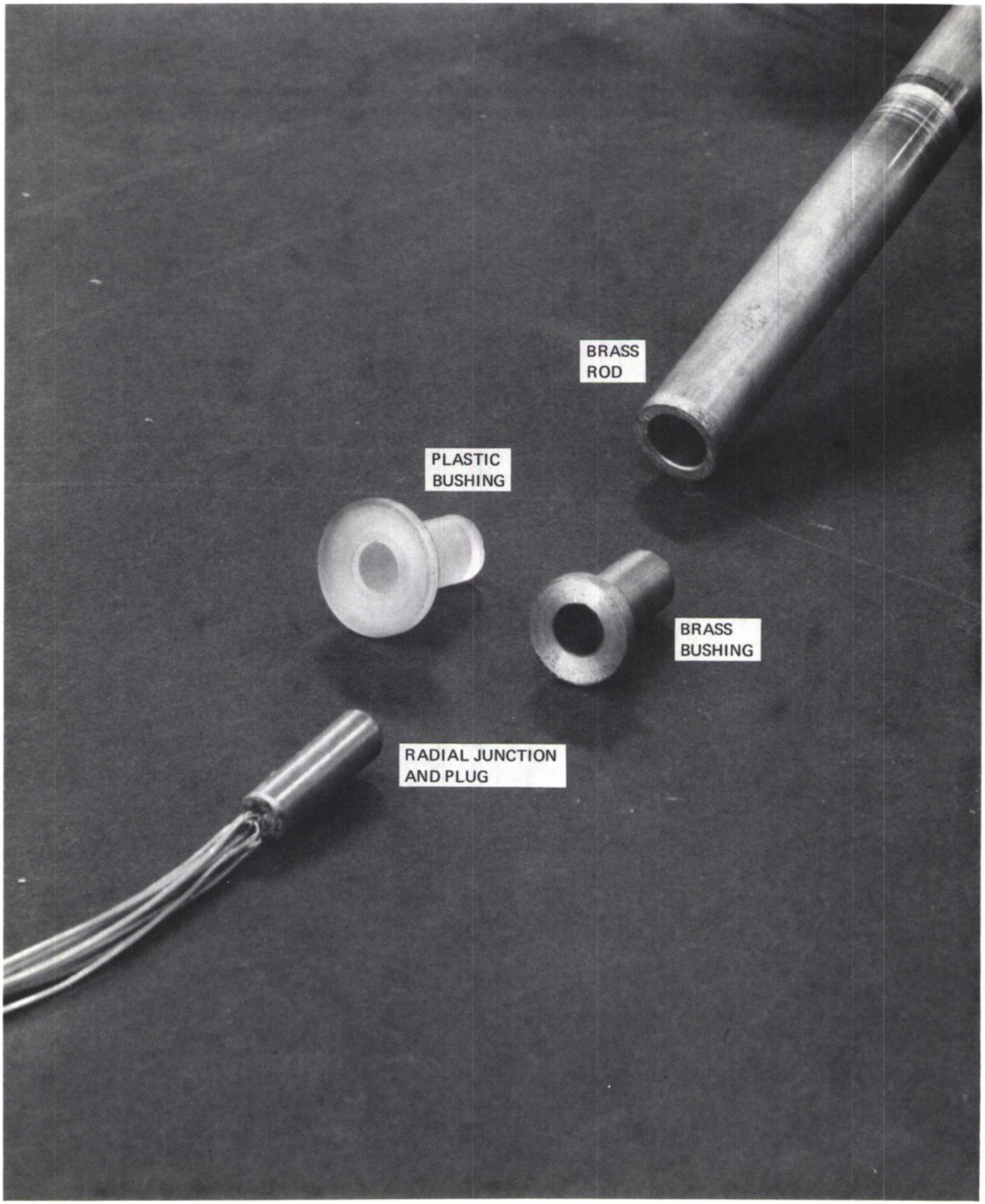


Figure 6. Photograph of Insulator Bushing

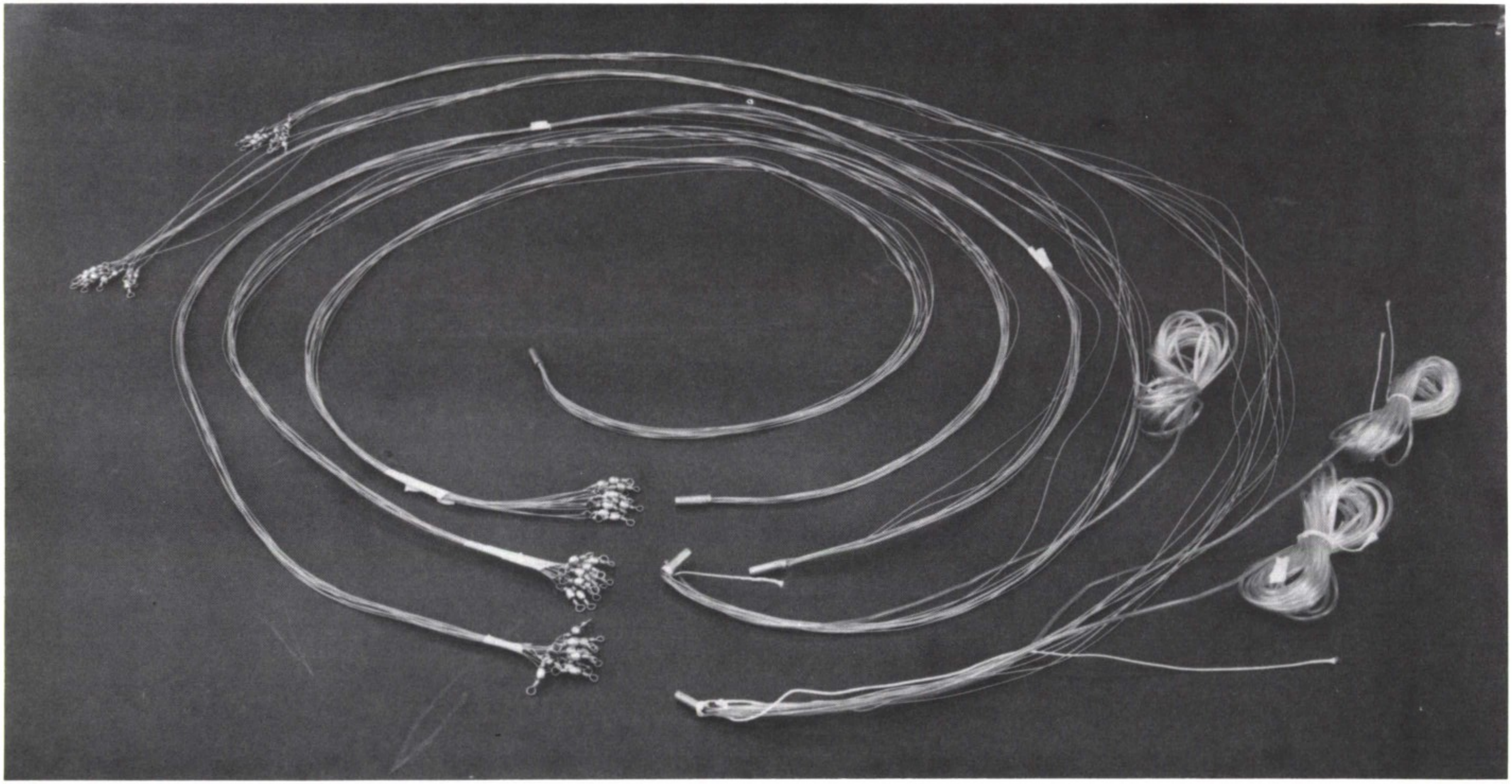


Figure 7. Photograph of Radials

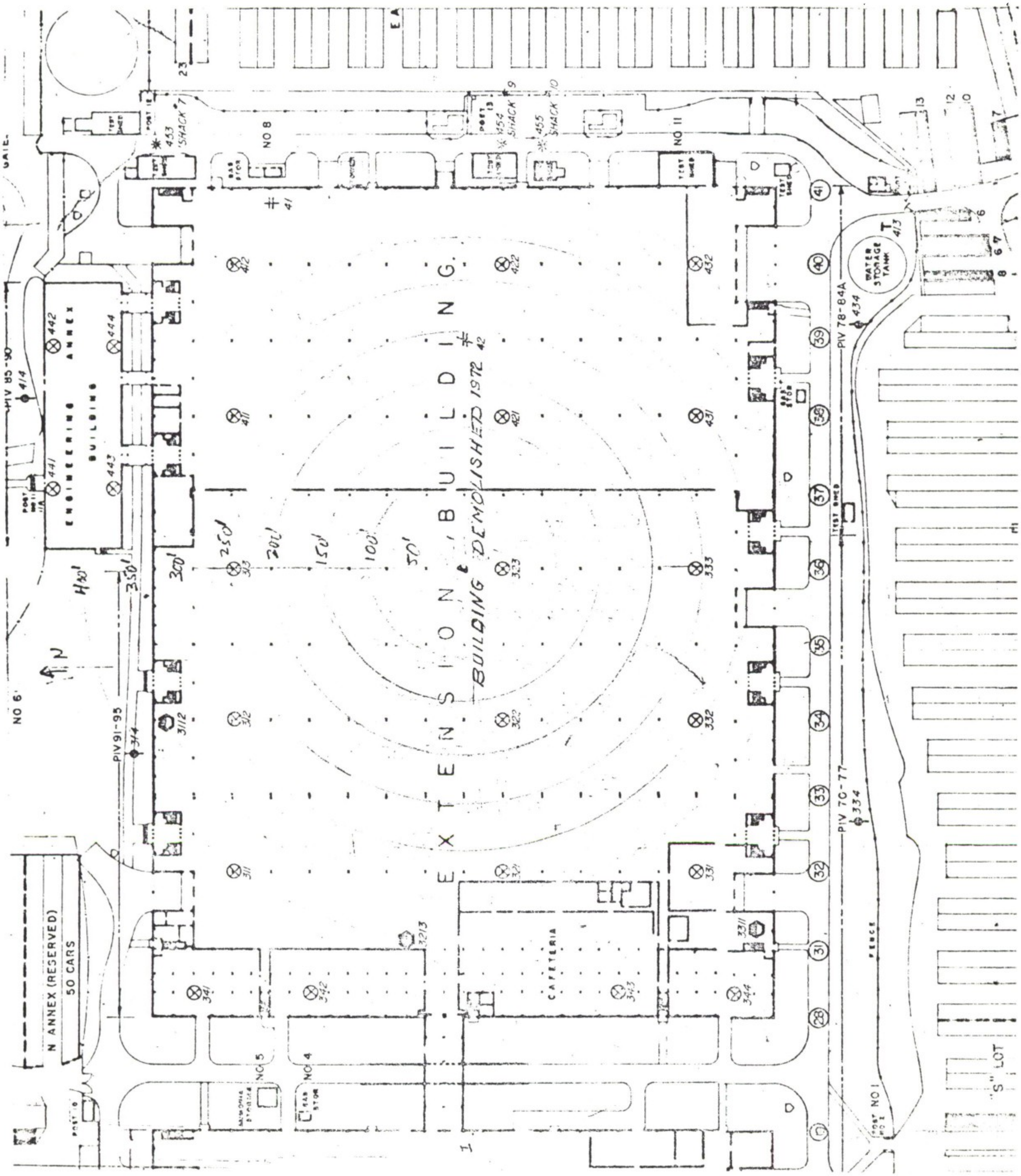


Figure 8. Map of East Field

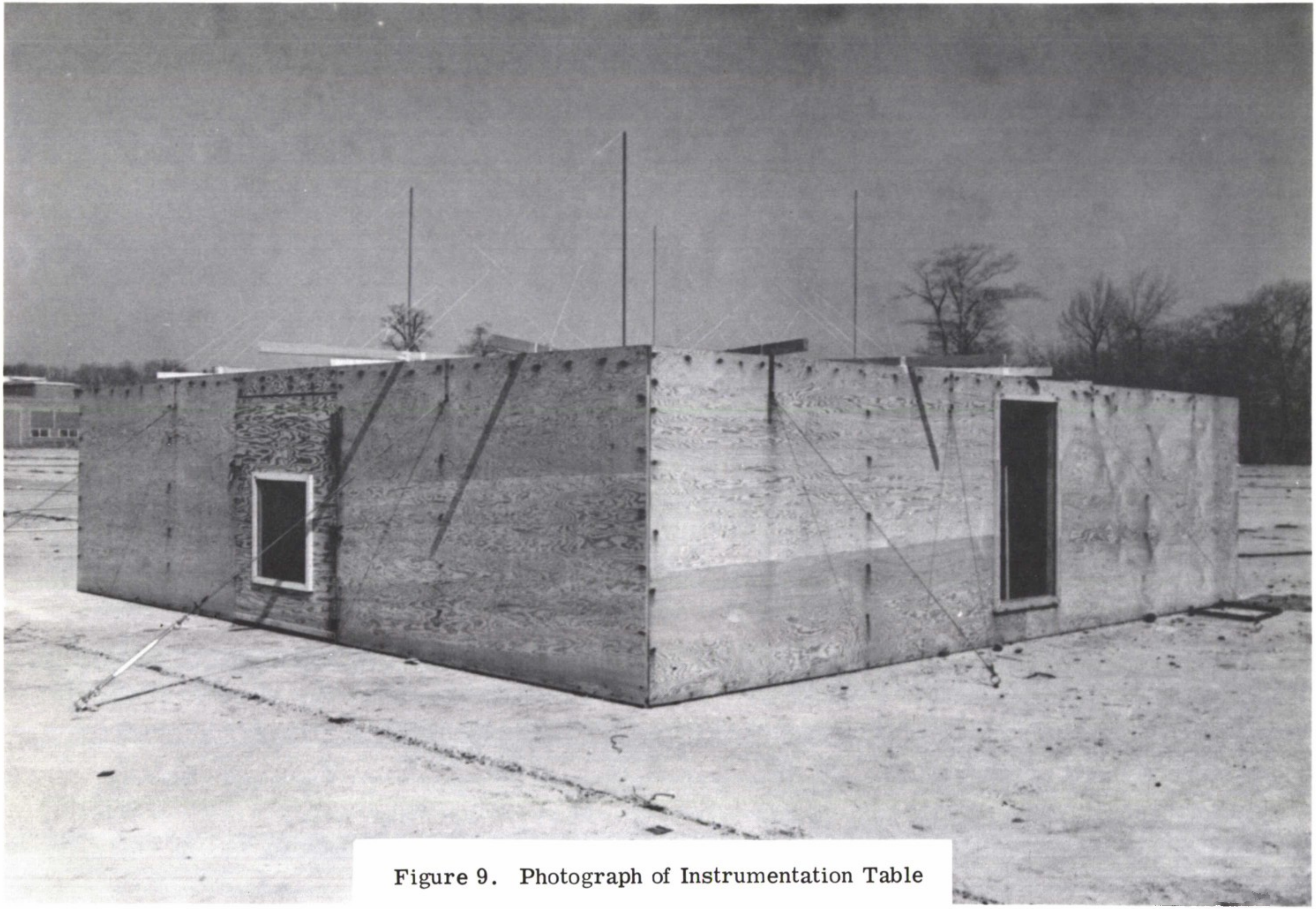


Figure 9. Photograph of Instrumentation Table

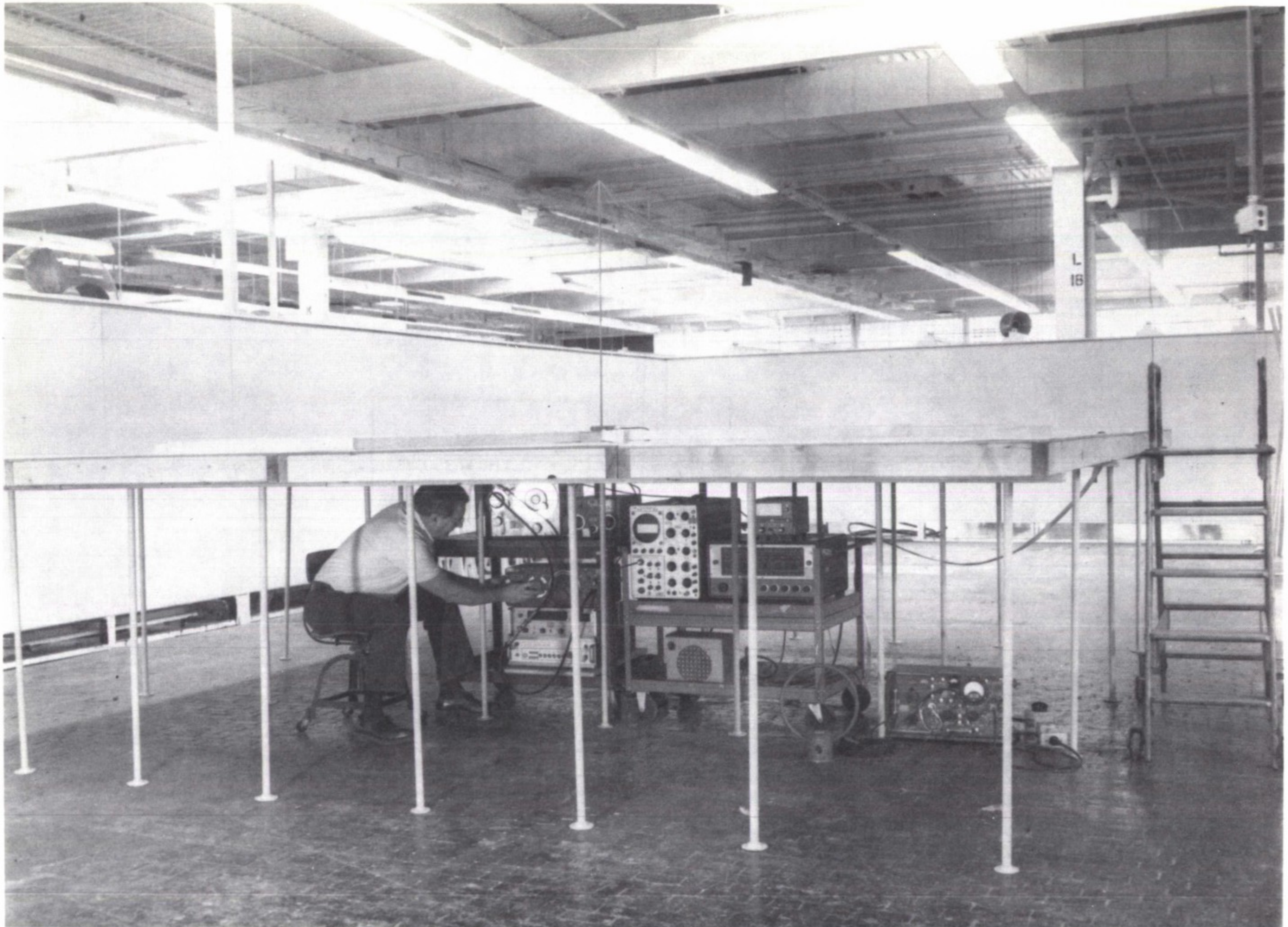


Figure 10. Photograph of Instrumentation Table Interior (Sides Removed)

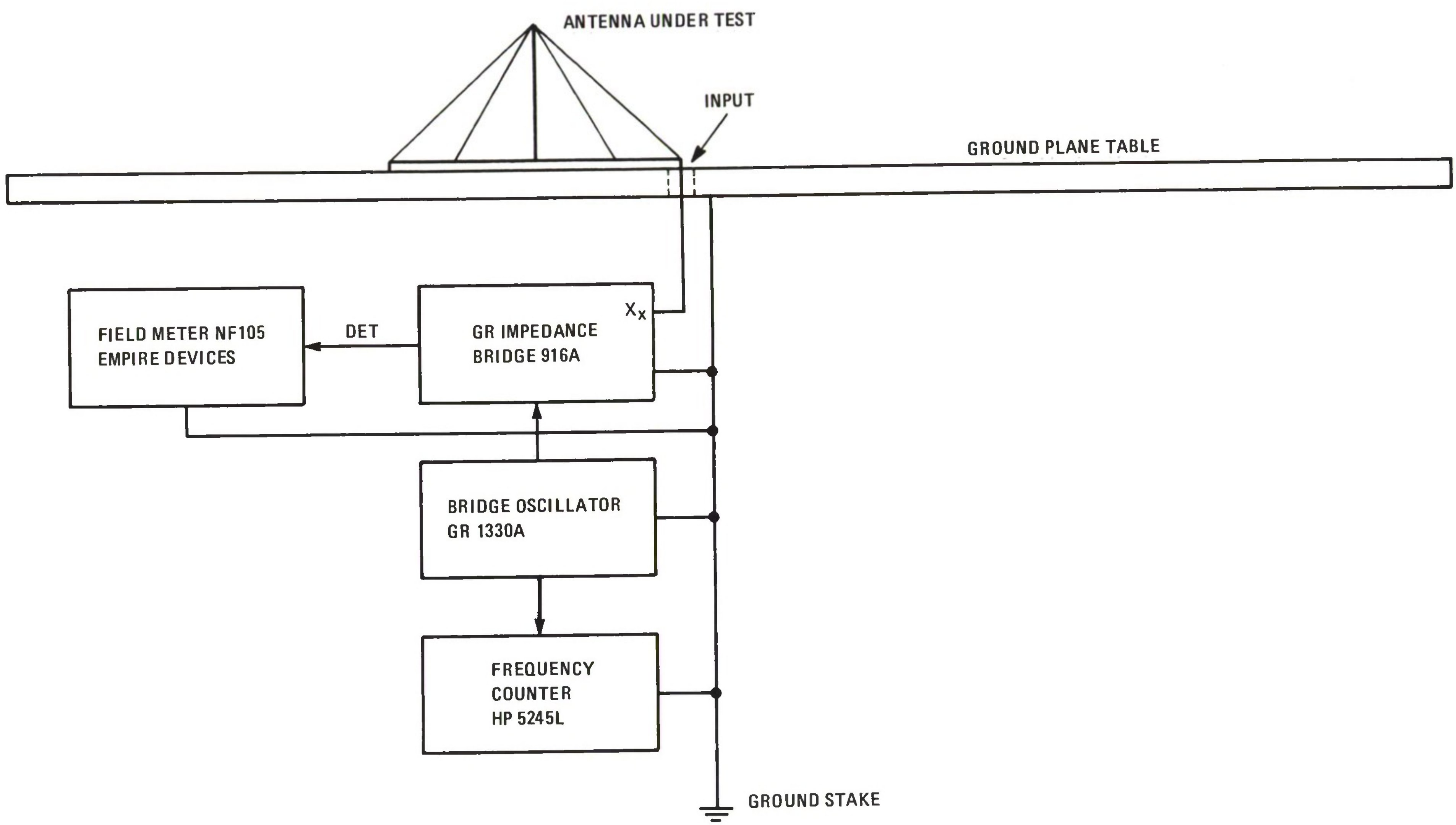


Figure 11. Impedance Measurements Test Equipment Set-Up

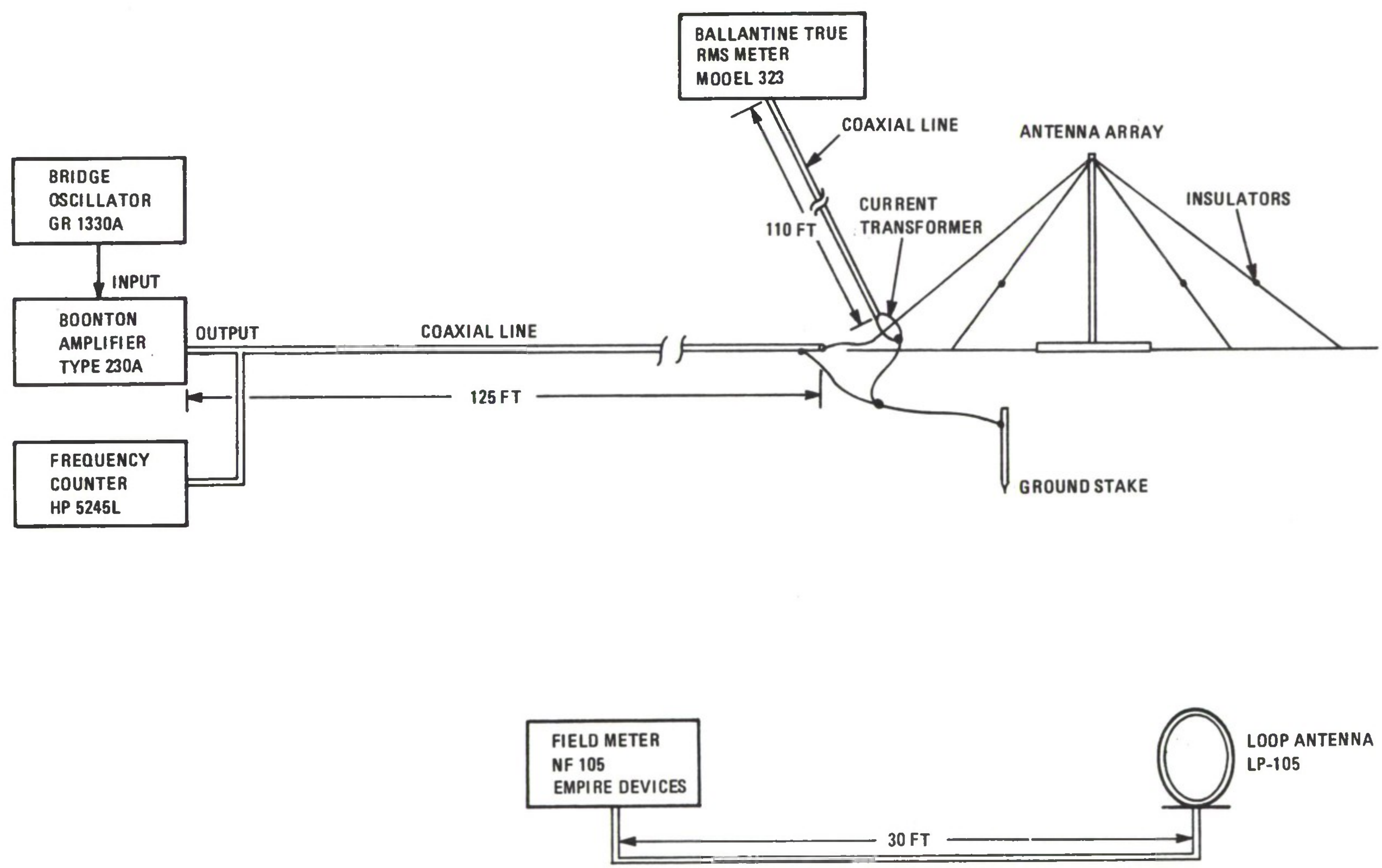


Figure 12. Field Intensity Measurements Test Equipment Set-Up

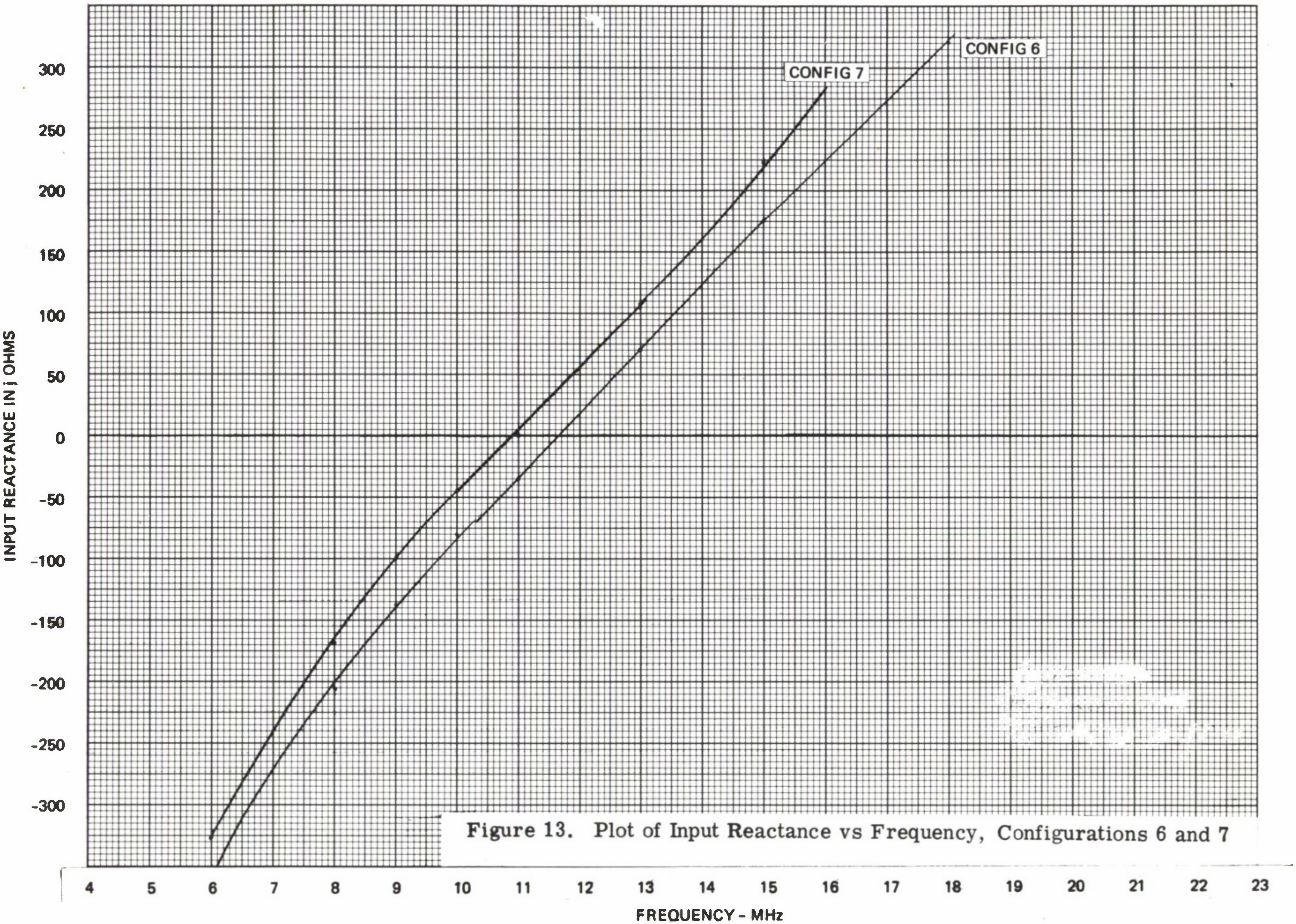


Figure 13. Plot of Input Reactance vs Frequency, Configurations 6 and 7

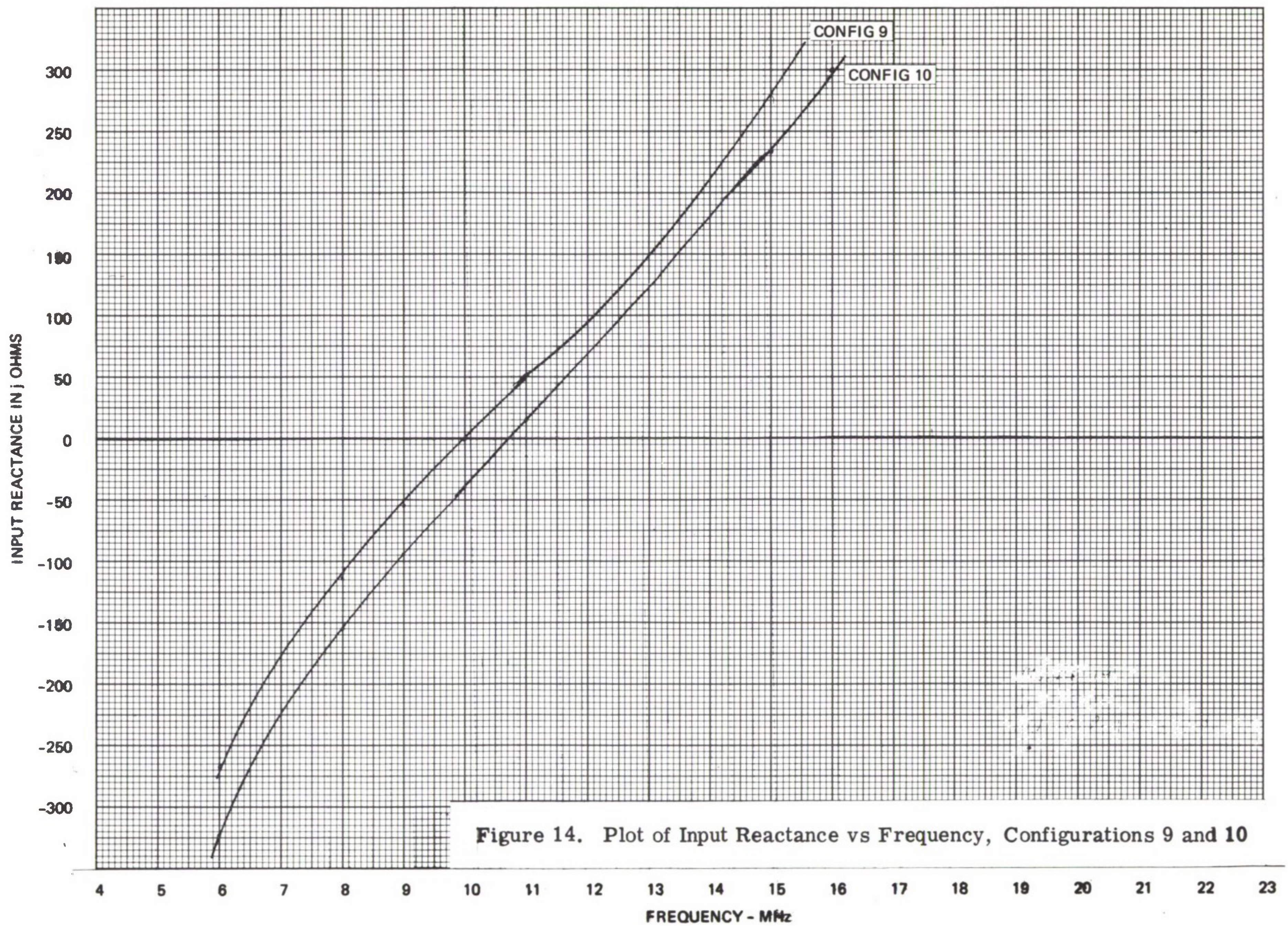


Figure 14. Plot of Input Reactance vs Frequency, Configurations 9 and 10

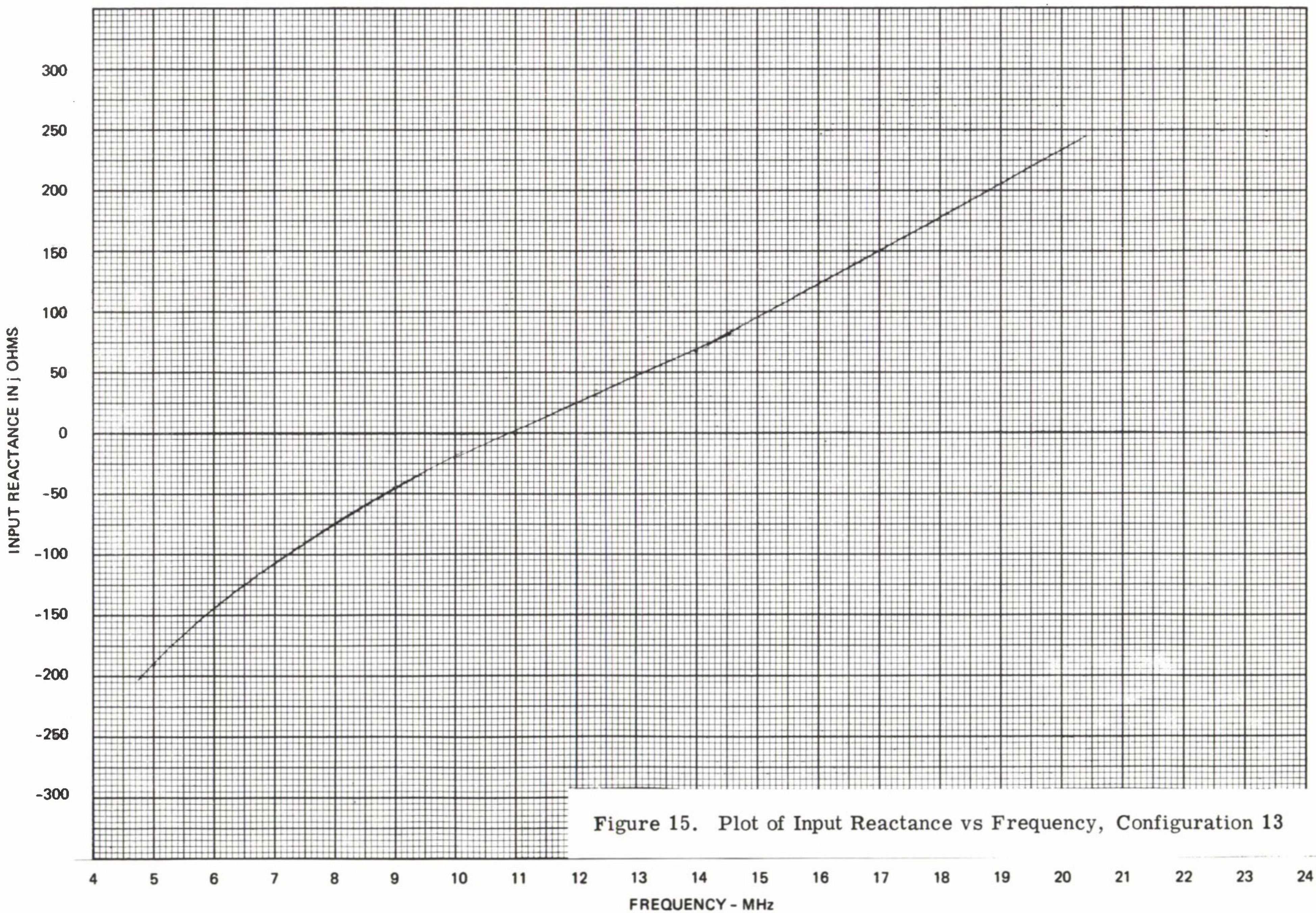


Figure 15. Plot of Input Reactance vs Frequency, Configuration 13

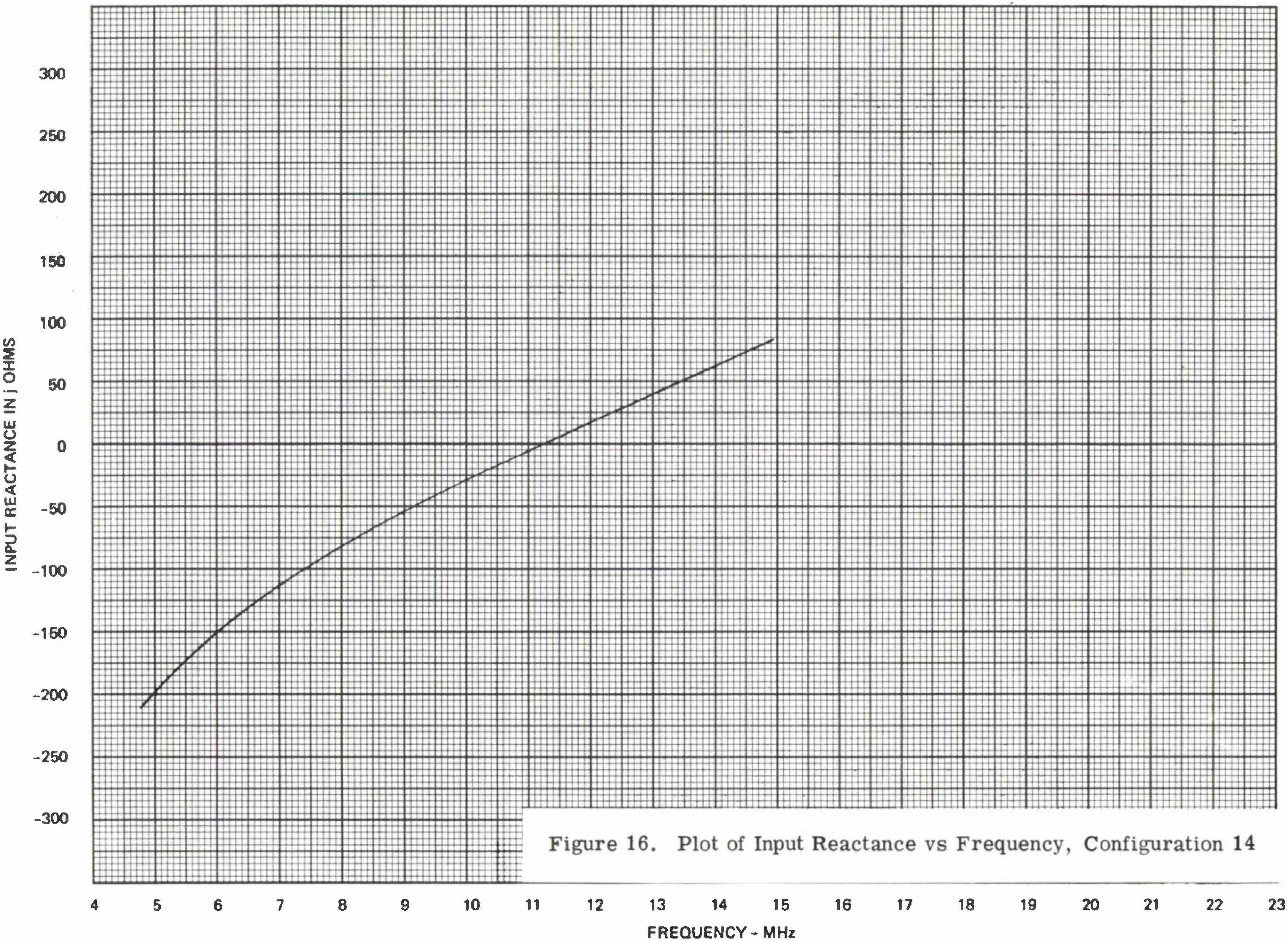


Figure 16. Plot of Input Reactance vs Frequency, Configuration 14

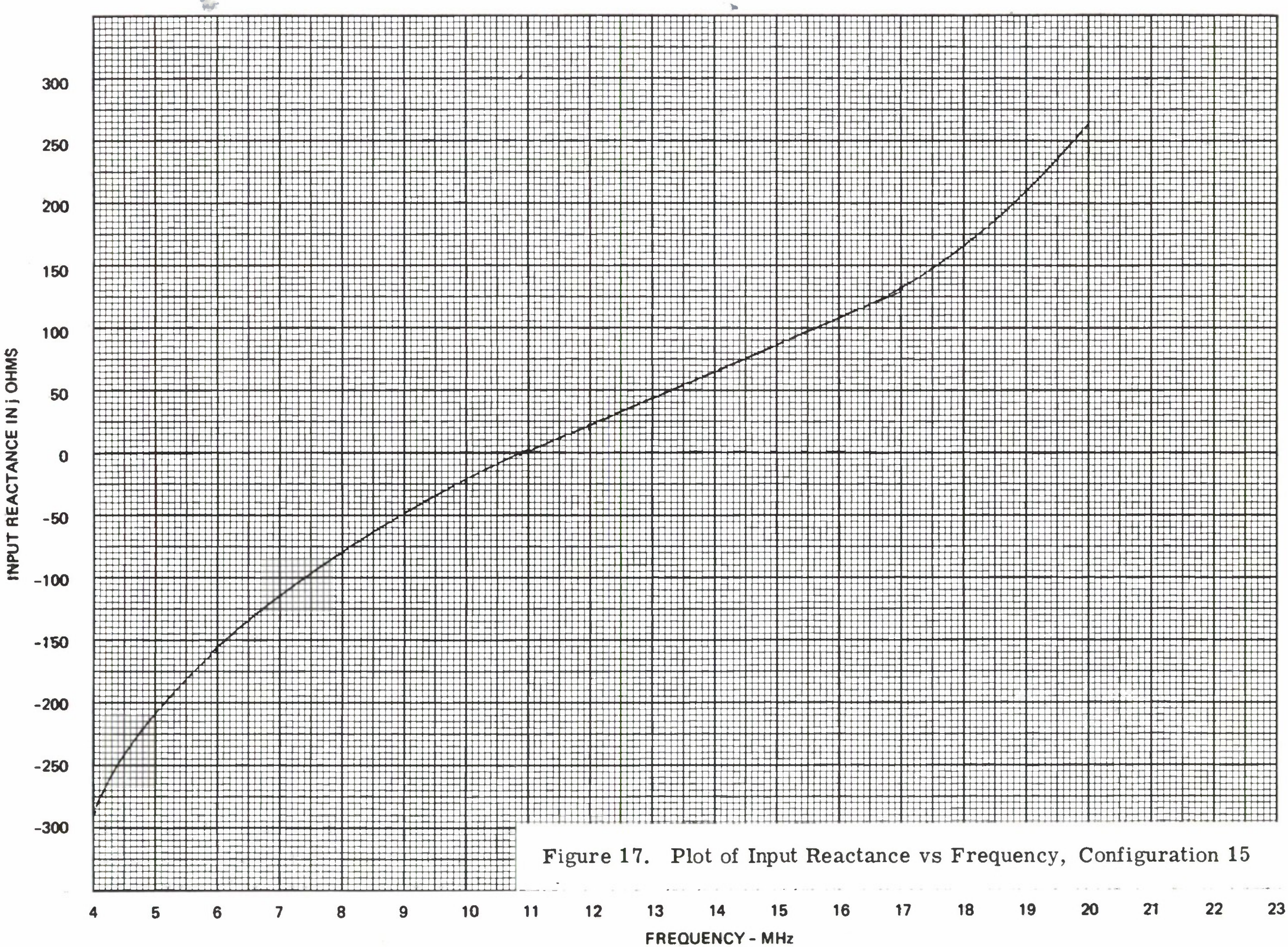


Figure 17. Plot of Input Reactance vs Frequency, Configuration 15

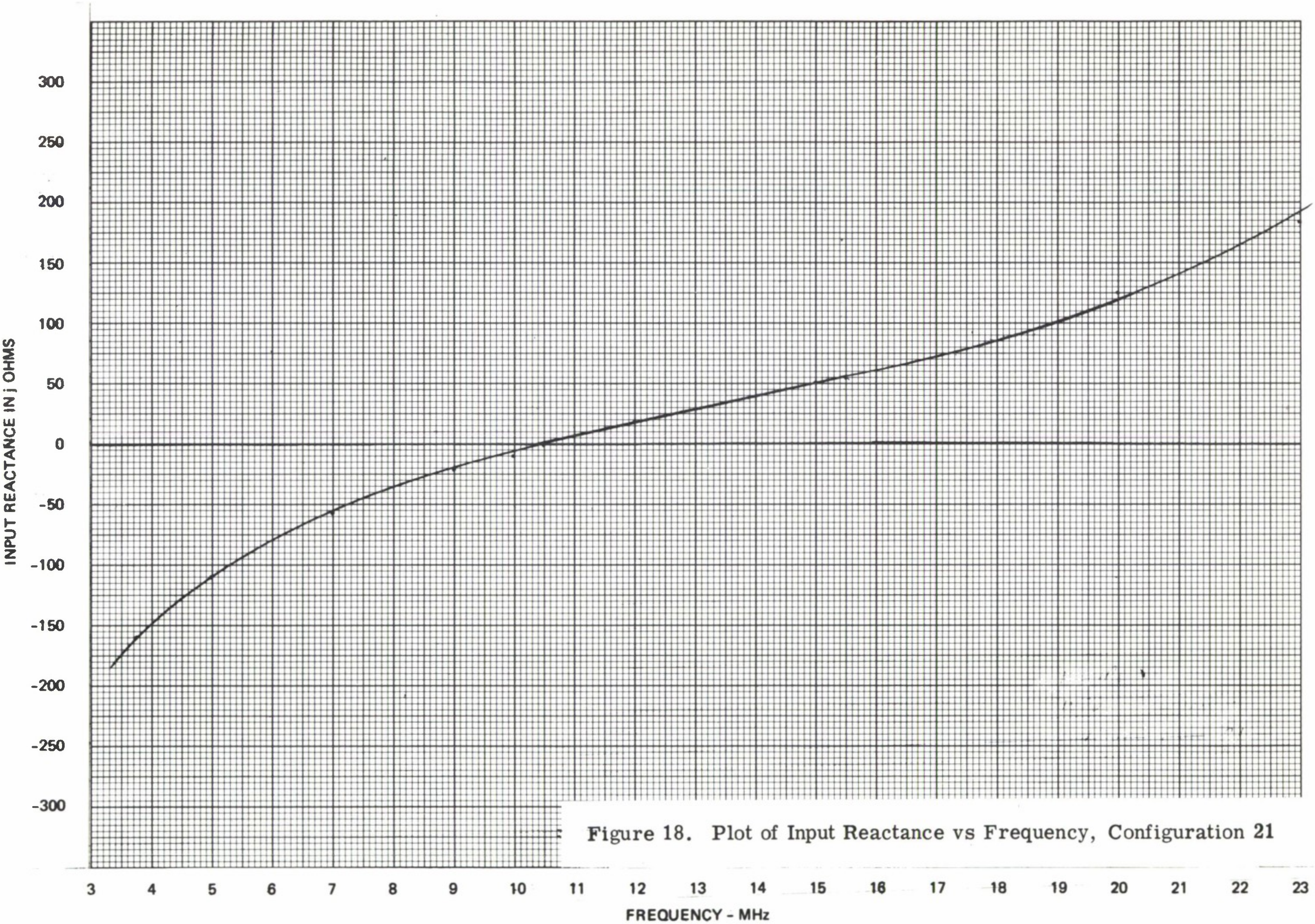


Figure 18. Plot of Input Reactance vs Frequency, Configuration 21

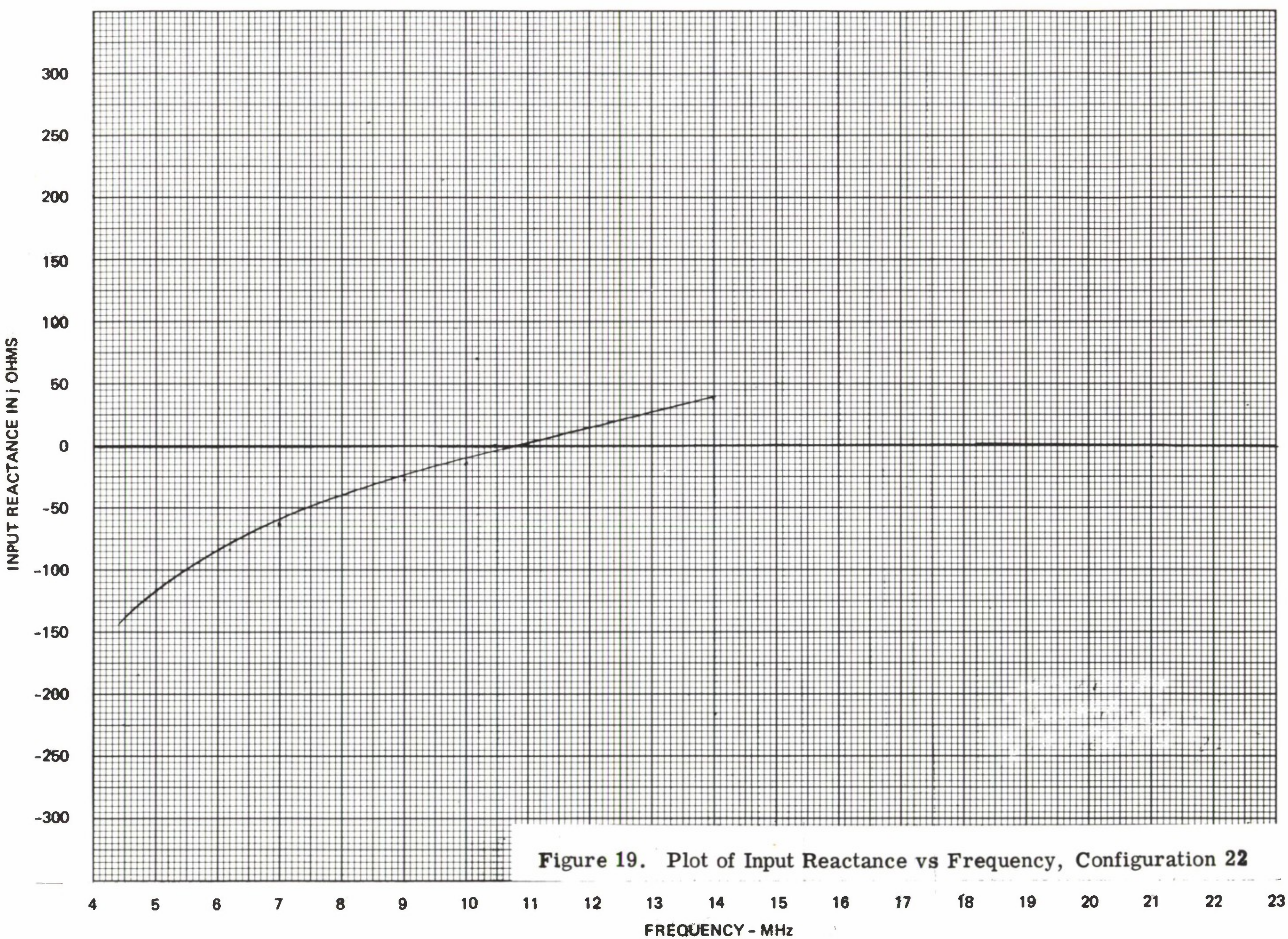


Figure 19. Plot of Input Reactance vs Frequency, Configuration 22

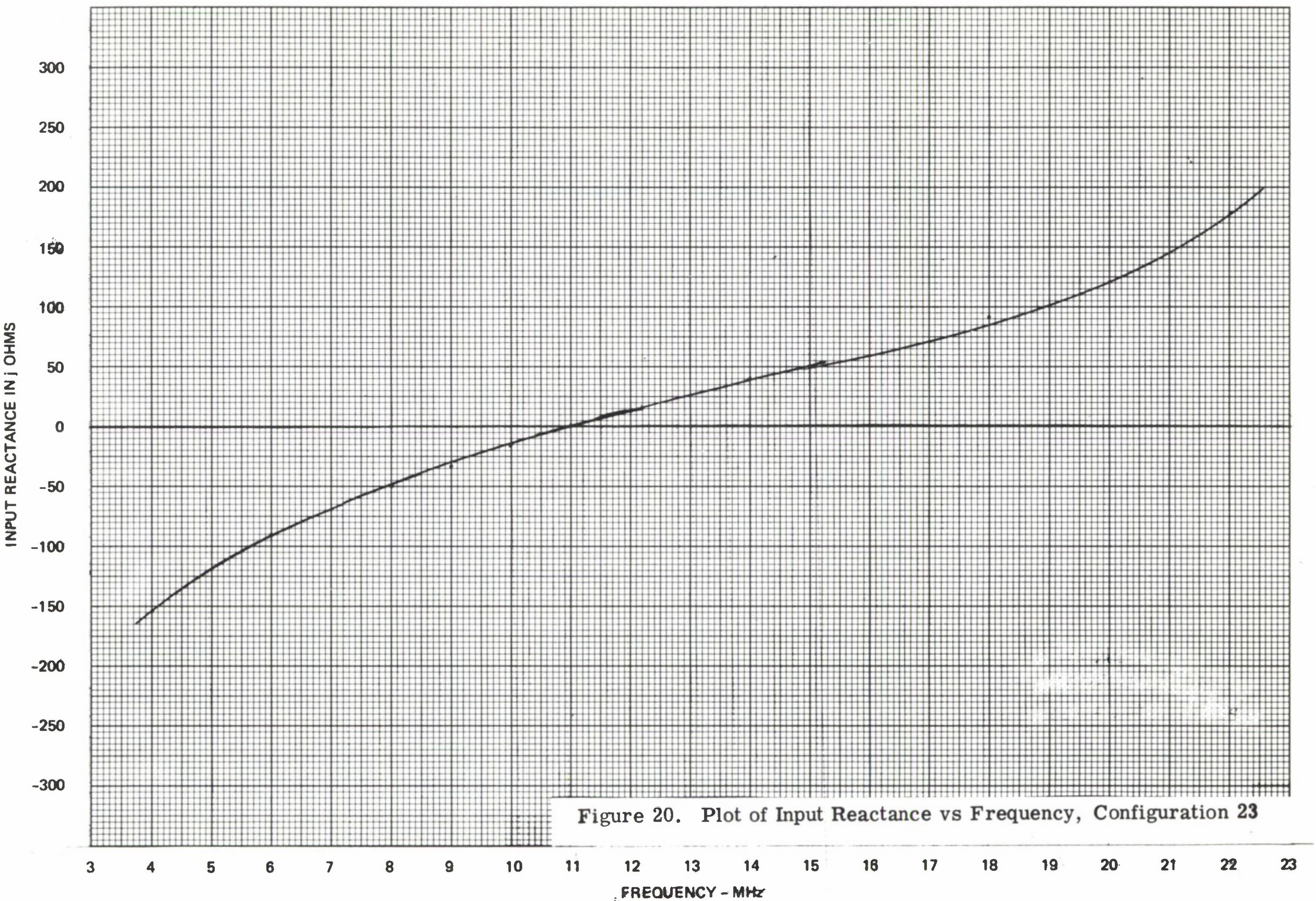


Figure 20. Plot of Input Reactance vs Frequency, Configuration 23

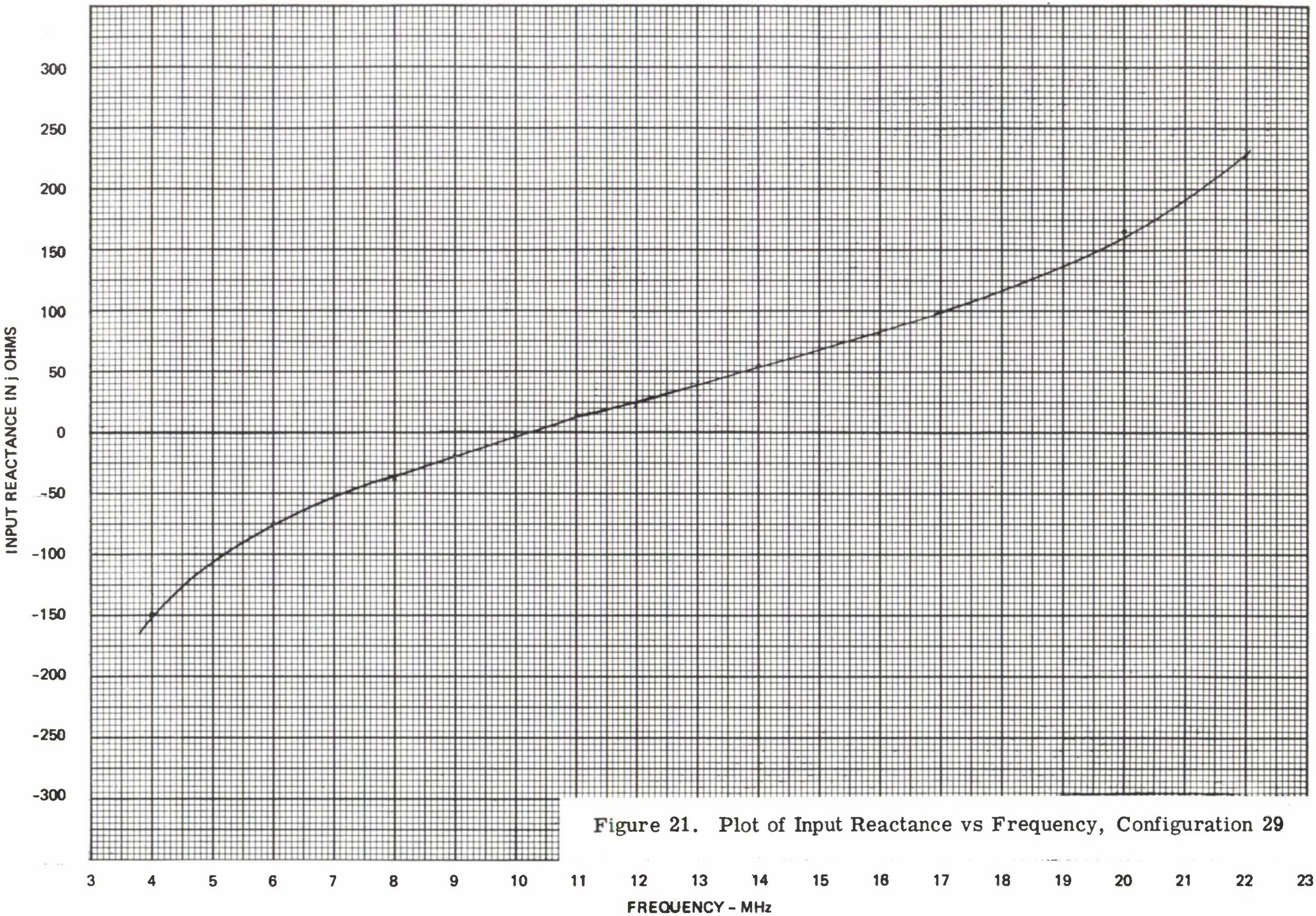


Figure 21. Plot of Input Reactance vs Frequency, Configuration 29

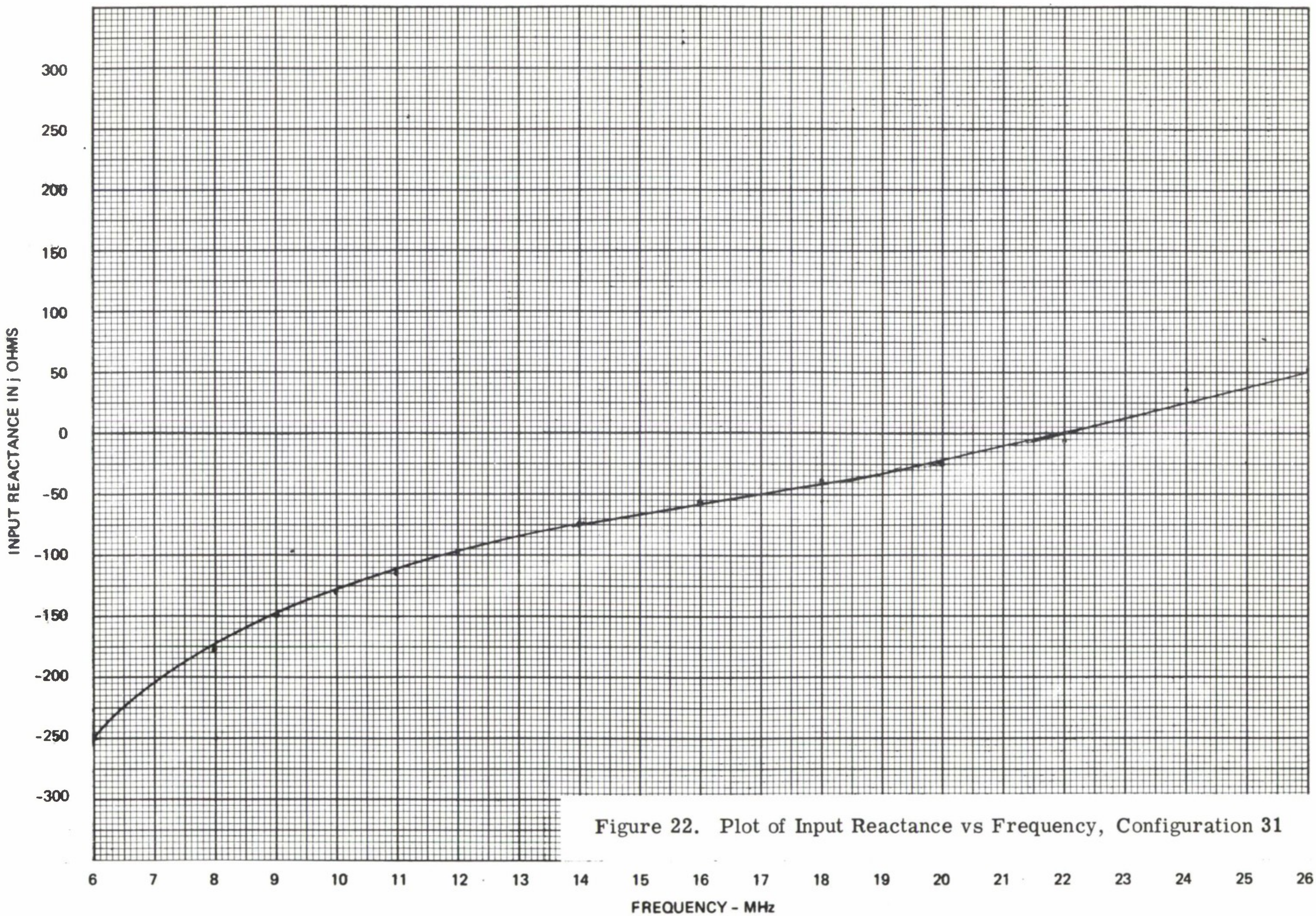


Figure 22. Plot of Input Reactance vs Frequency, Configuration 31

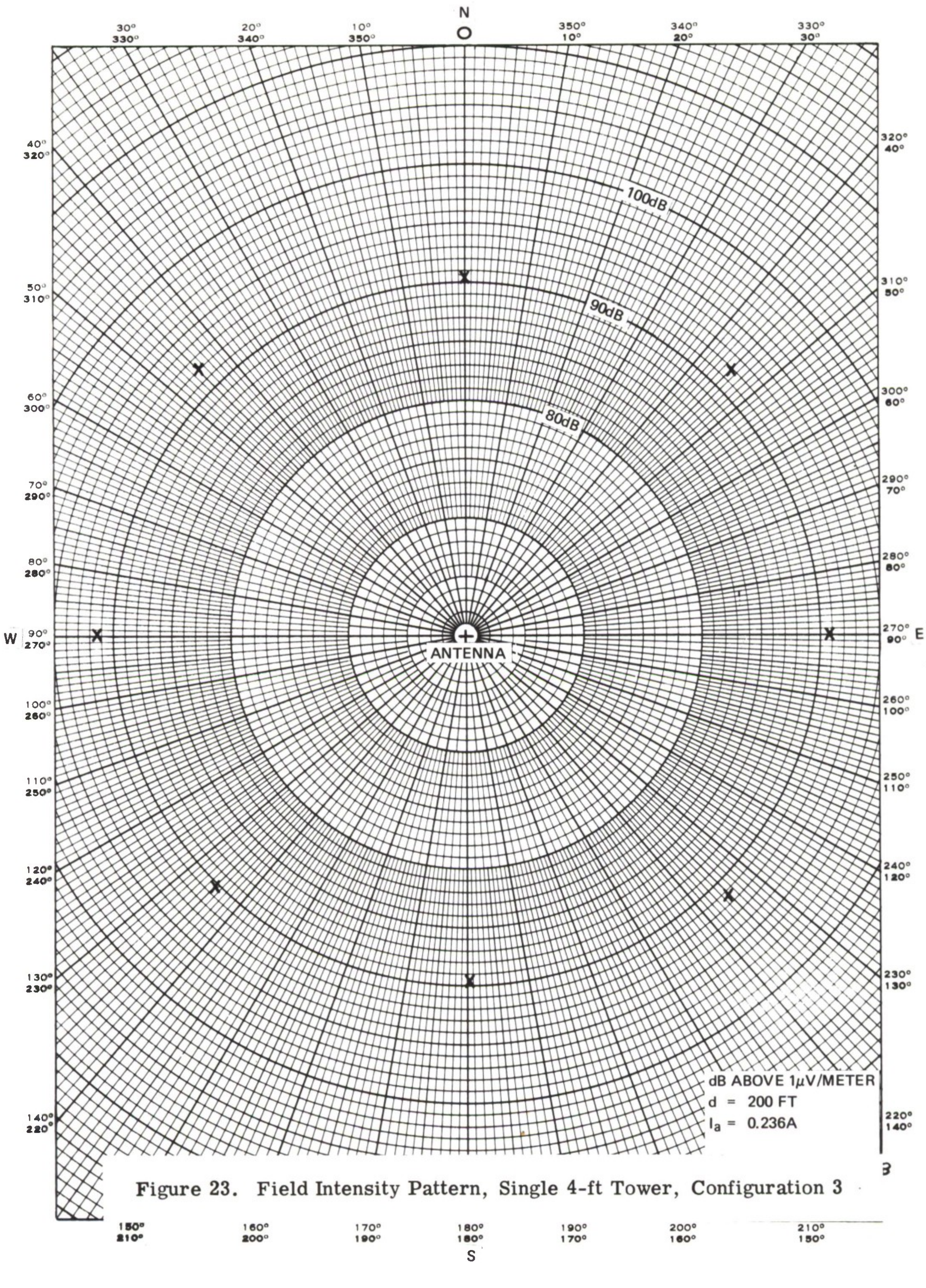


Figure 23. Field Intensity Pattern, Single 4-ft Tower, Configuration 3

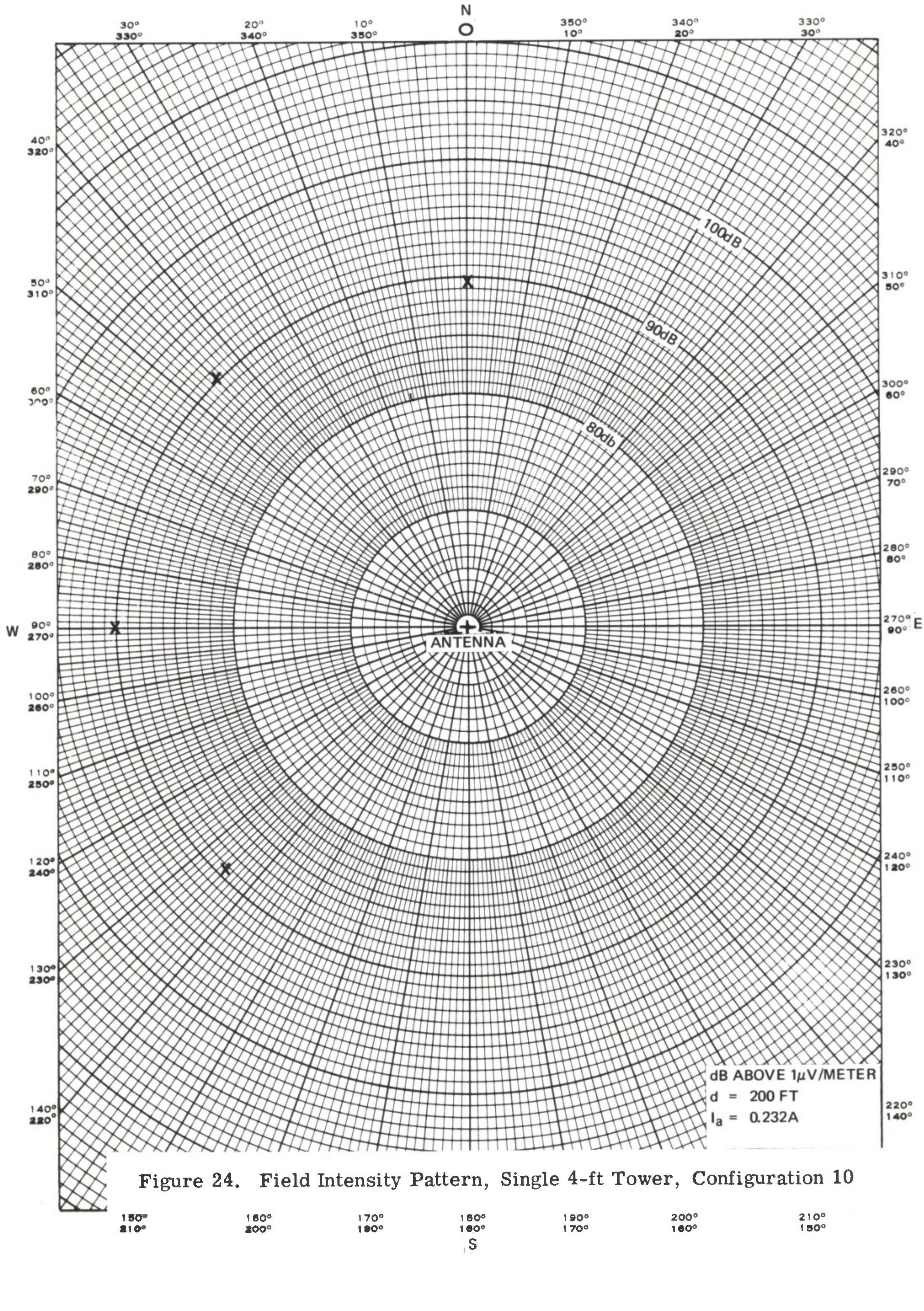


Figure 24. Field Intensity Pattern, Single 4-ft Tower, Configuration 10

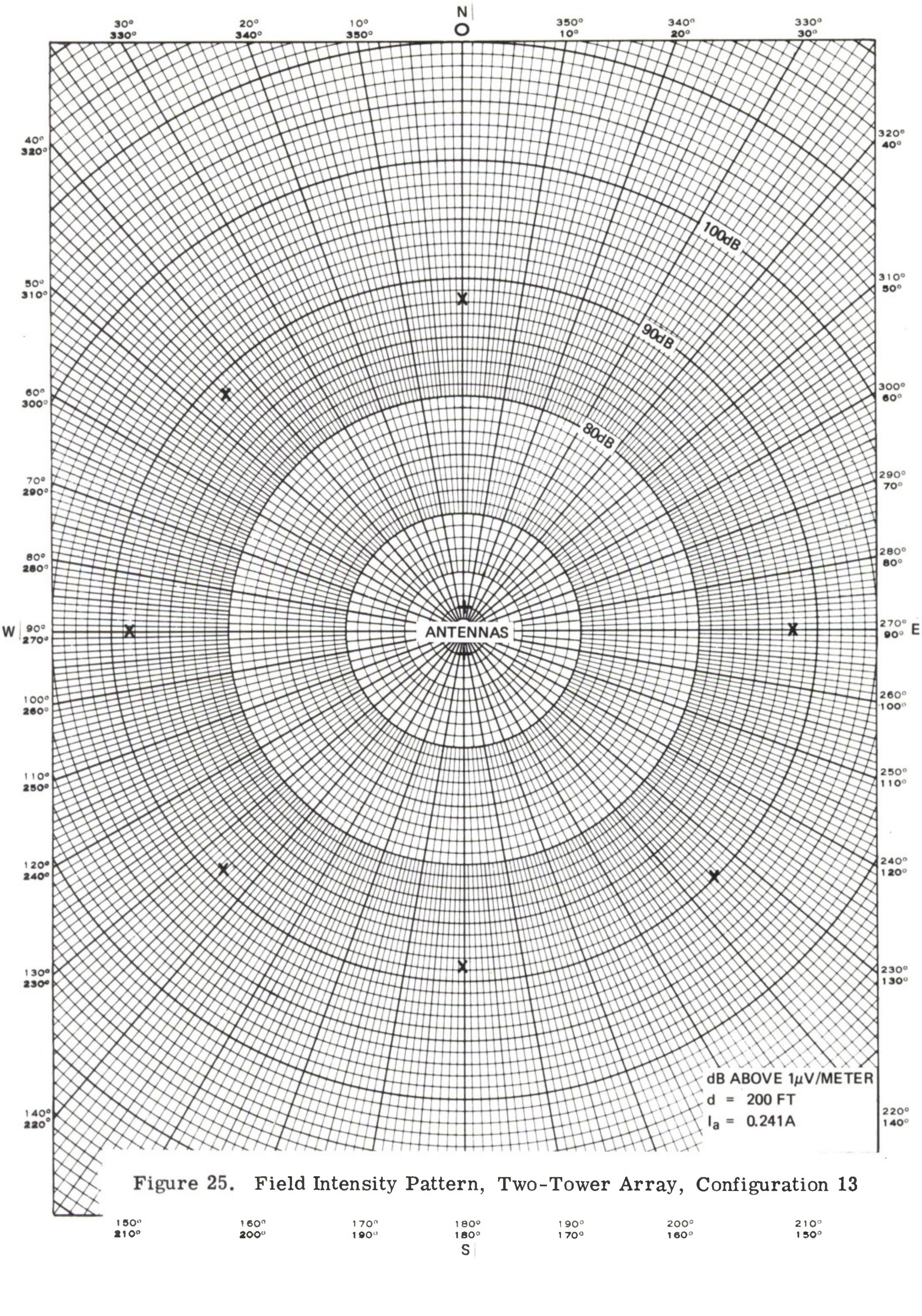


Figure 25. Field Intensity Pattern, Two-Tower Array, Configuration 13

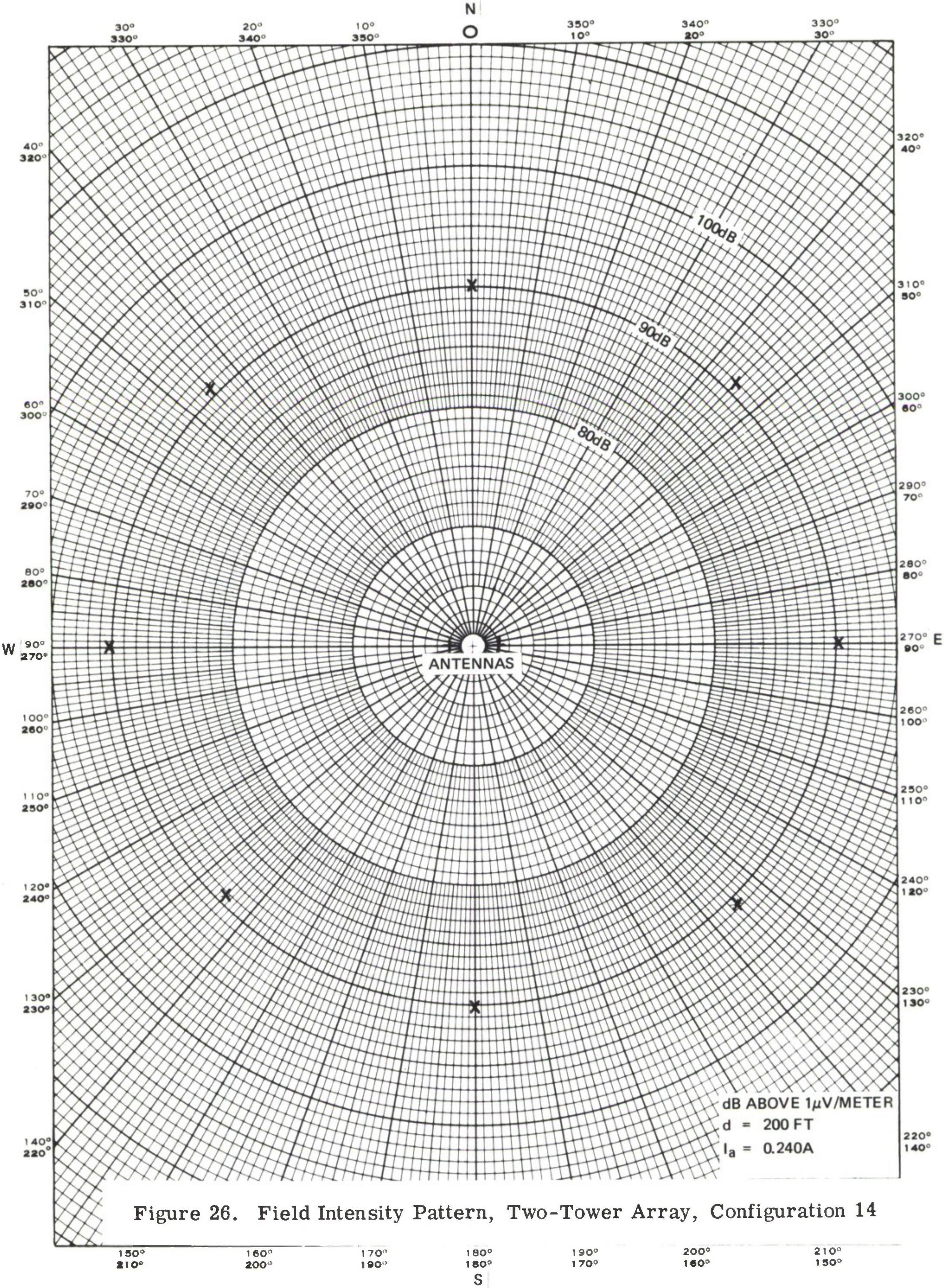


Figure 26. Field Intensity Pattern, Two-Tower Array, Configuration 14

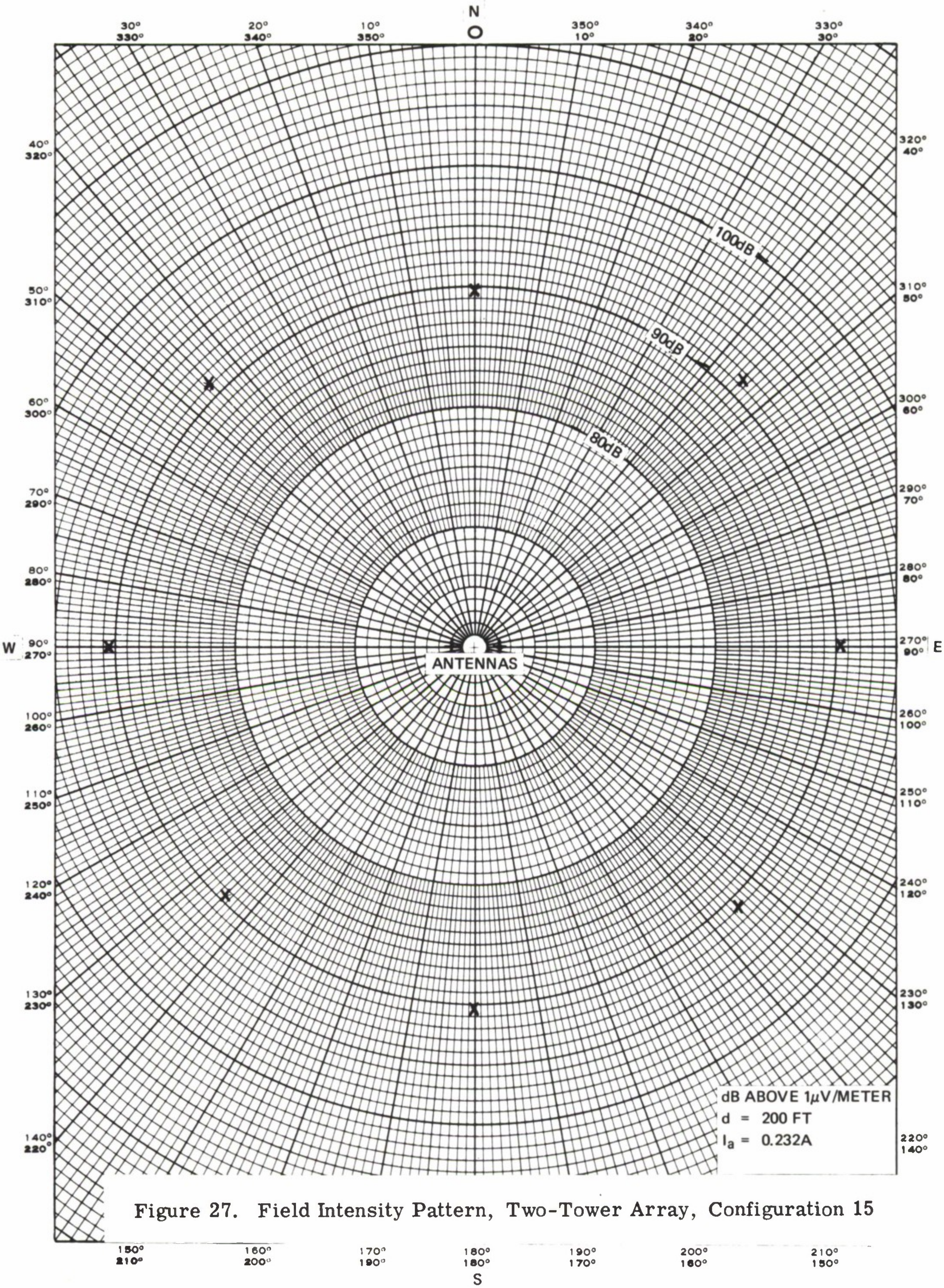


Figure 27. Field Intensity Pattern, Two-Tower Array, Configuration 15

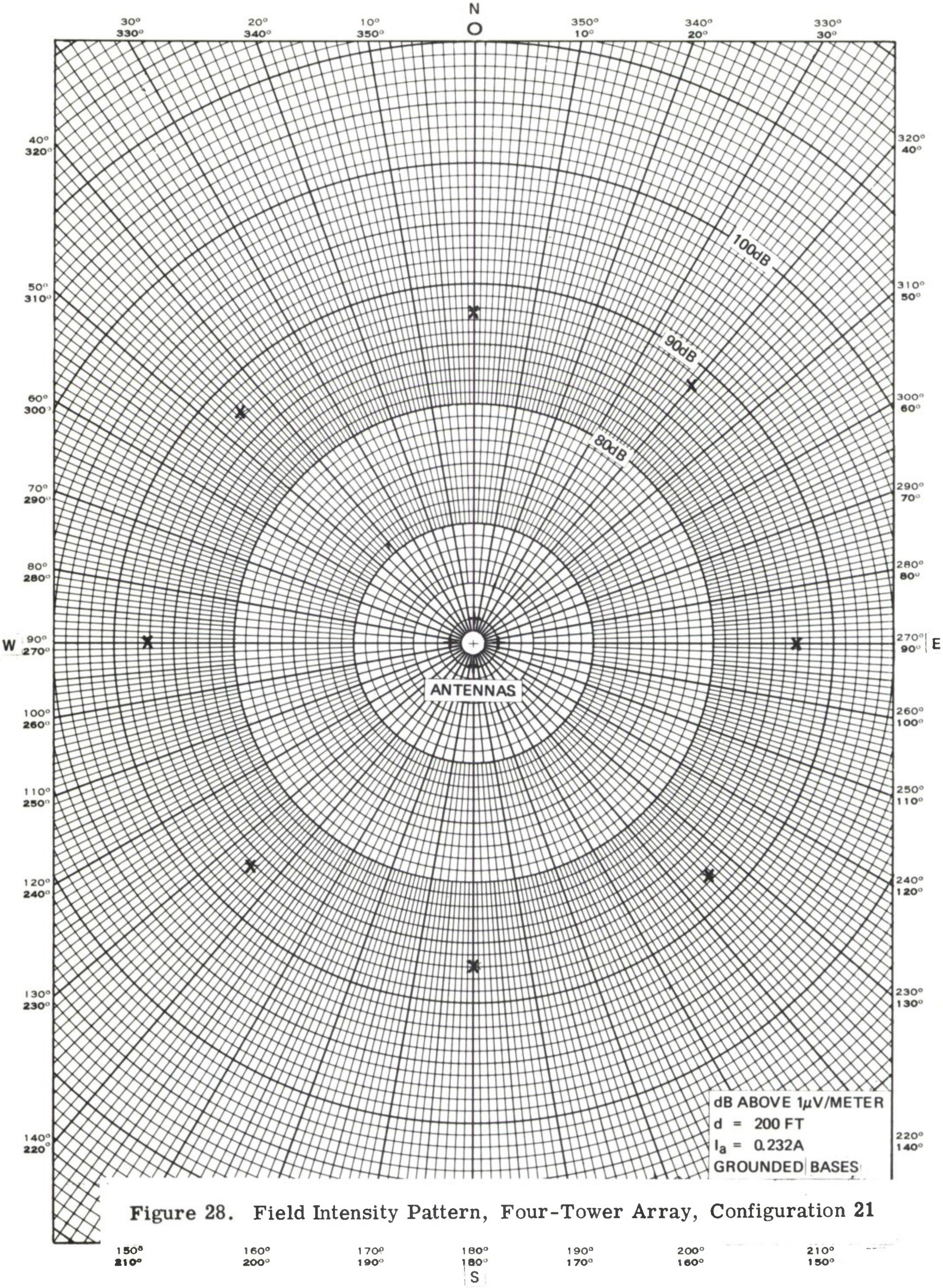


Figure 28. Field Intensity Pattern, Four-Tower Array, Configuration 21

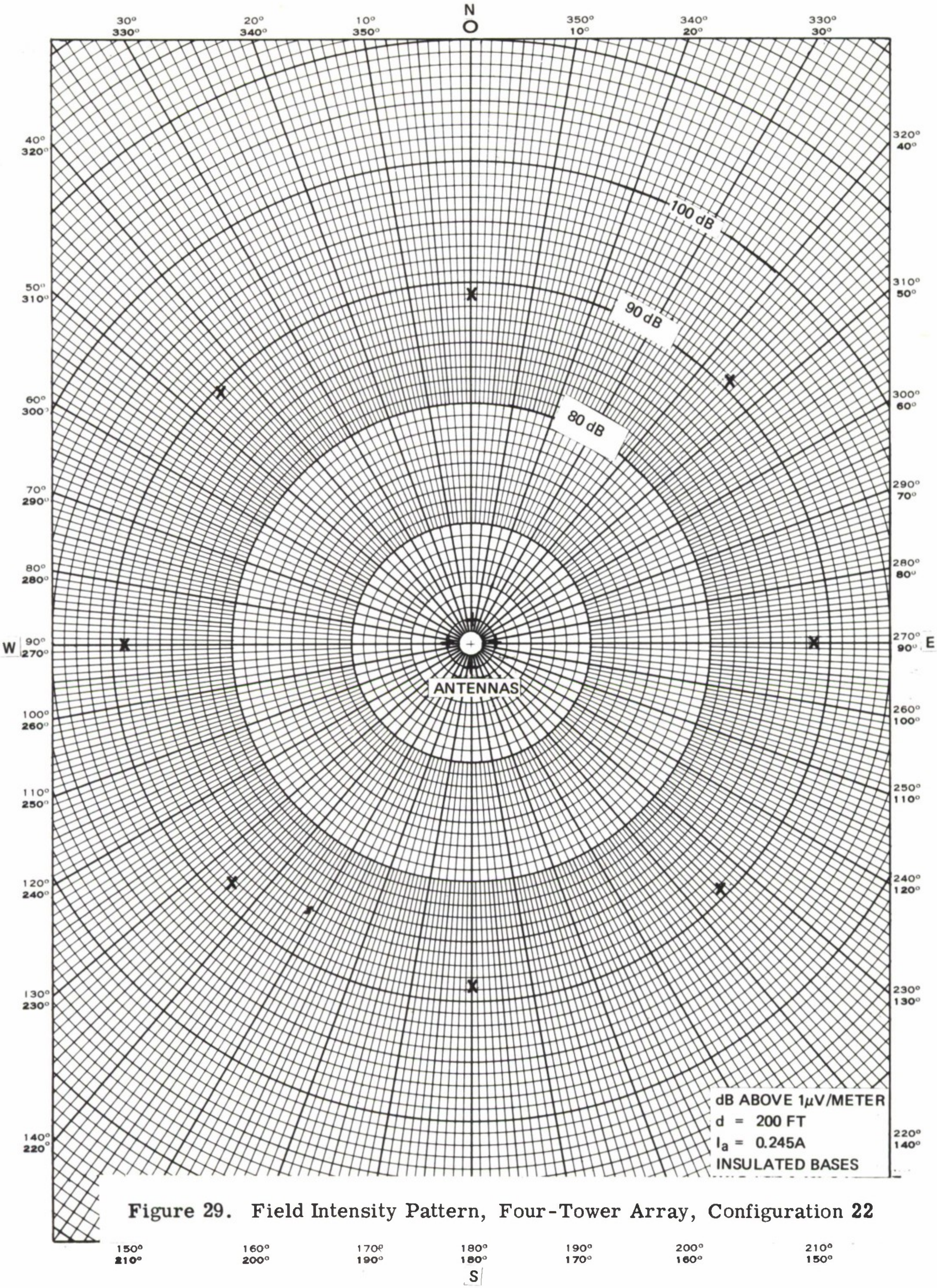


Figure 29. Field Intensity Pattern, Four-Tower Array, Configuration 22

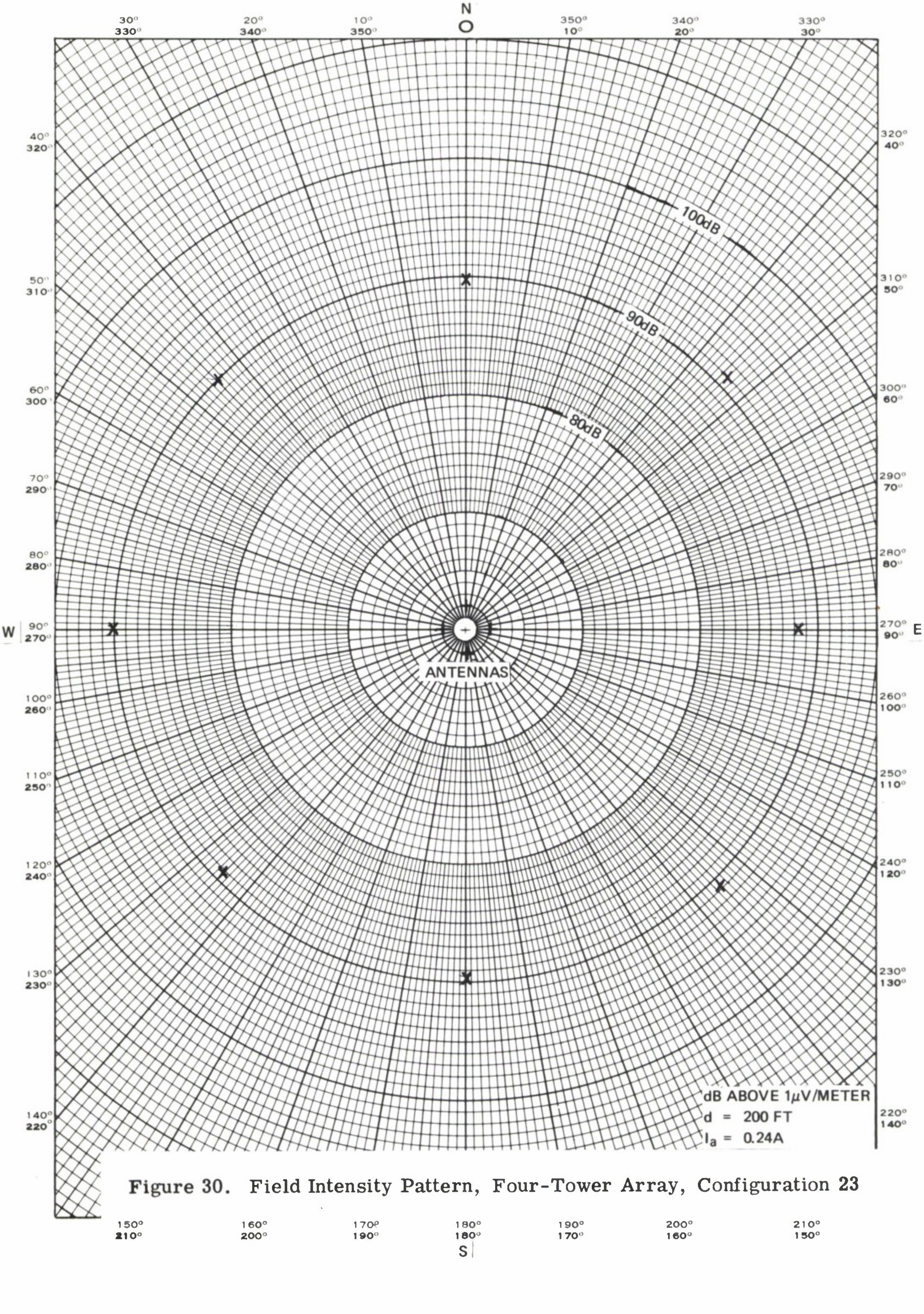


Figure 30. Field Intensity Pattern, Four-Tower Array, Configuration 23

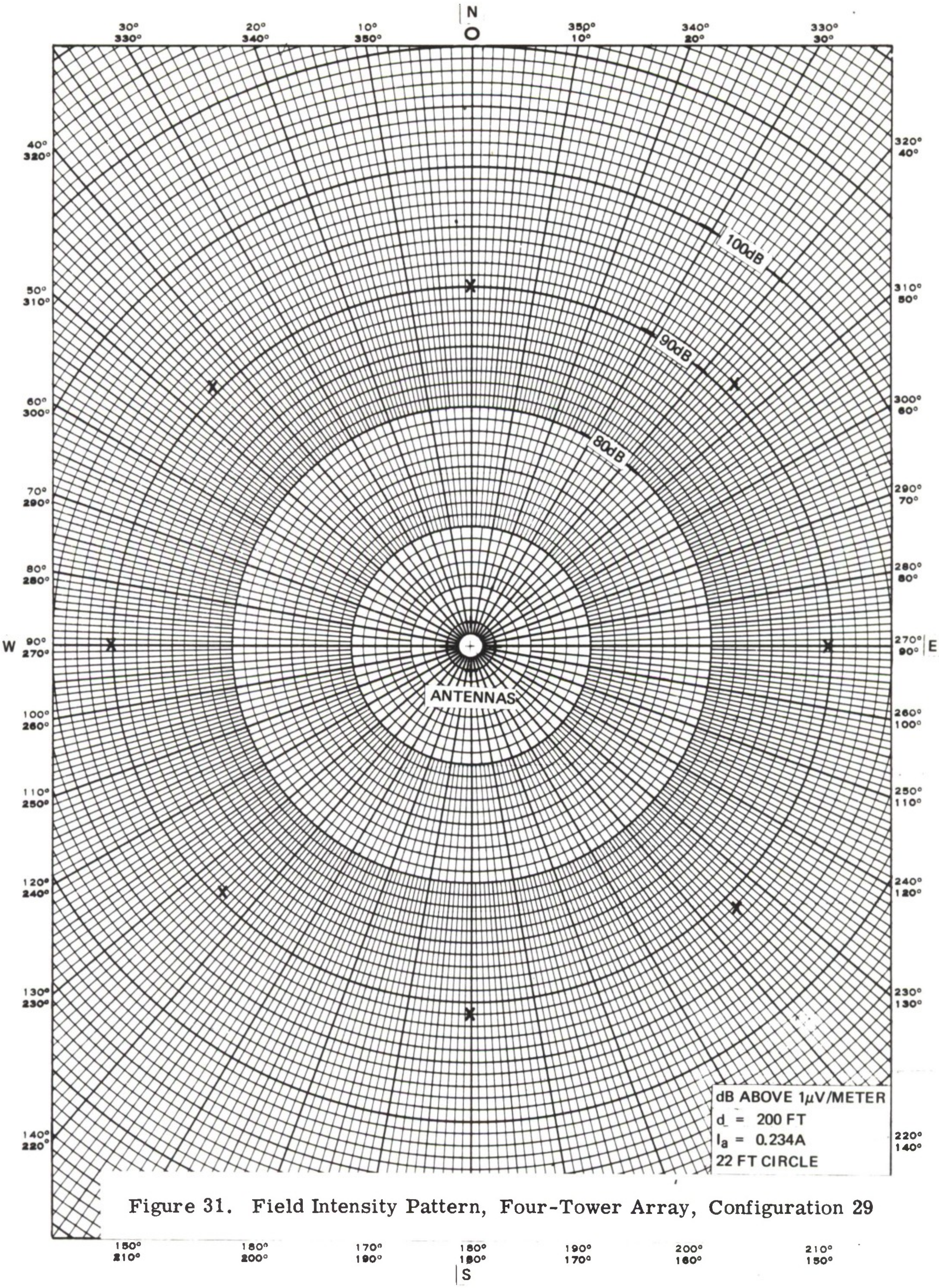


Figure 31. Field Intensity Pattern, Four-Tower Array, Configuration 29

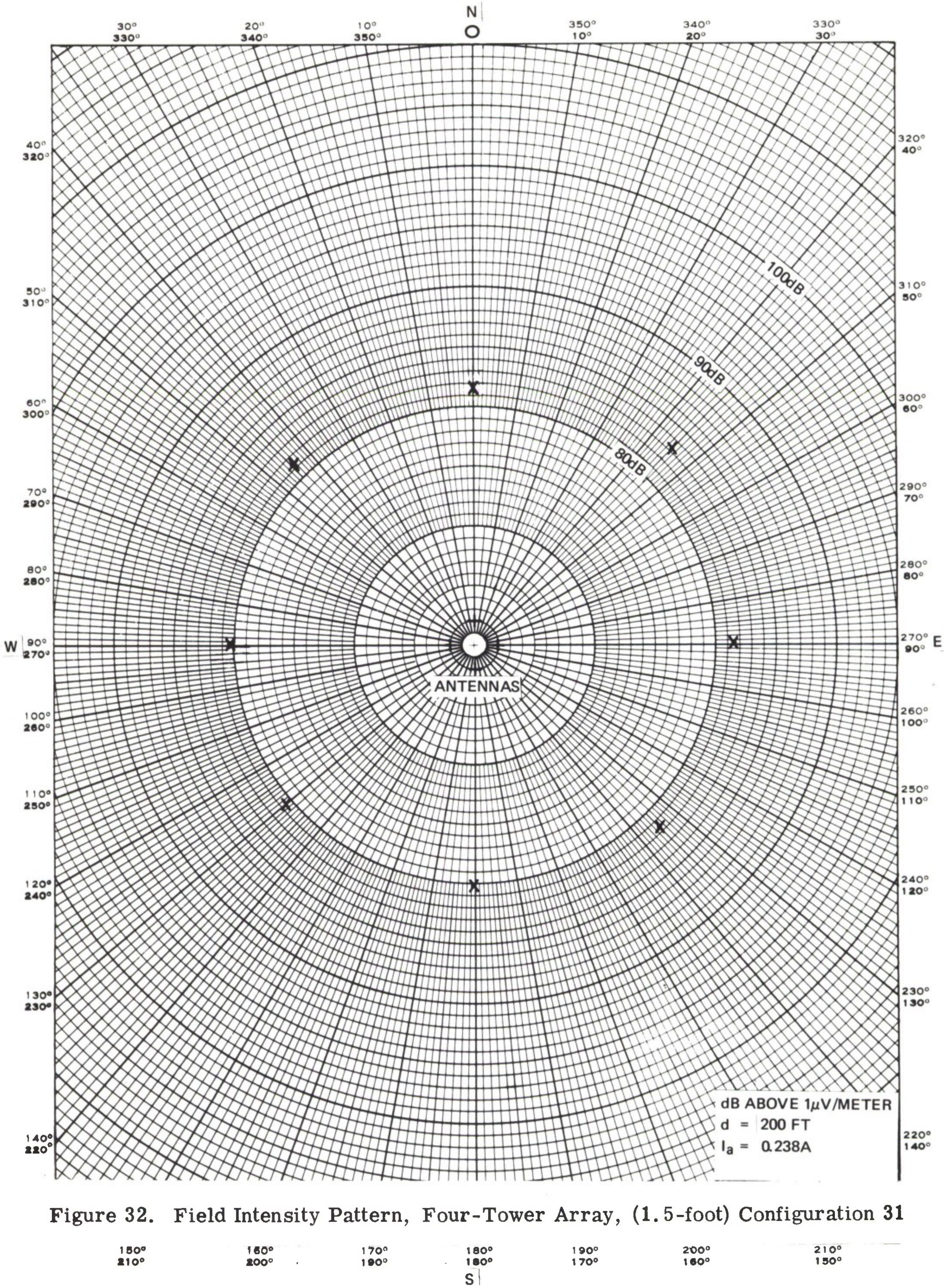


Figure 32. Field Intensity Pattern, Four-Tower Array, (1.5-foot) Configuration 31

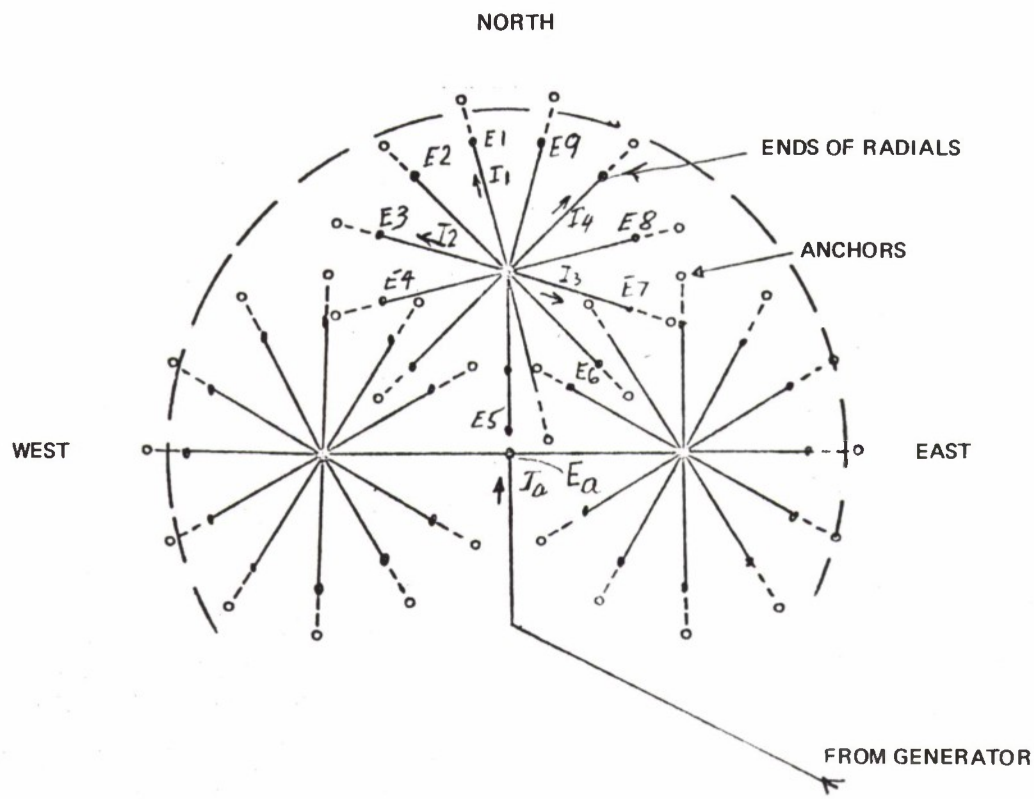


Figure 33. Induced Voltage and Current Measurements, Three-Tower Antenna Array

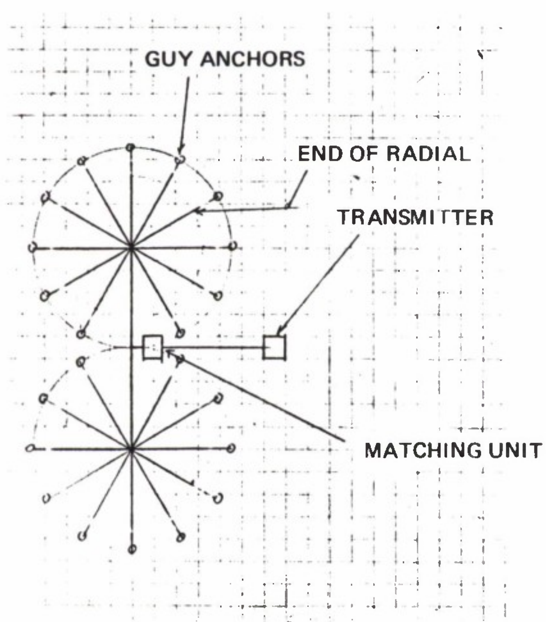


Figure 34. Two-Tower Array, Configuration 15, Top View

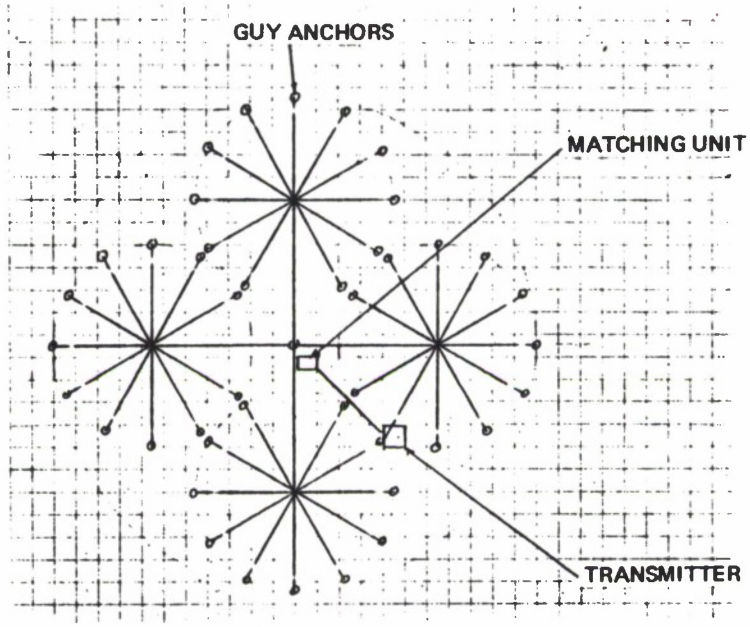


Figure 35. Four-Tower Array, Configurations 29 and 32, Top View

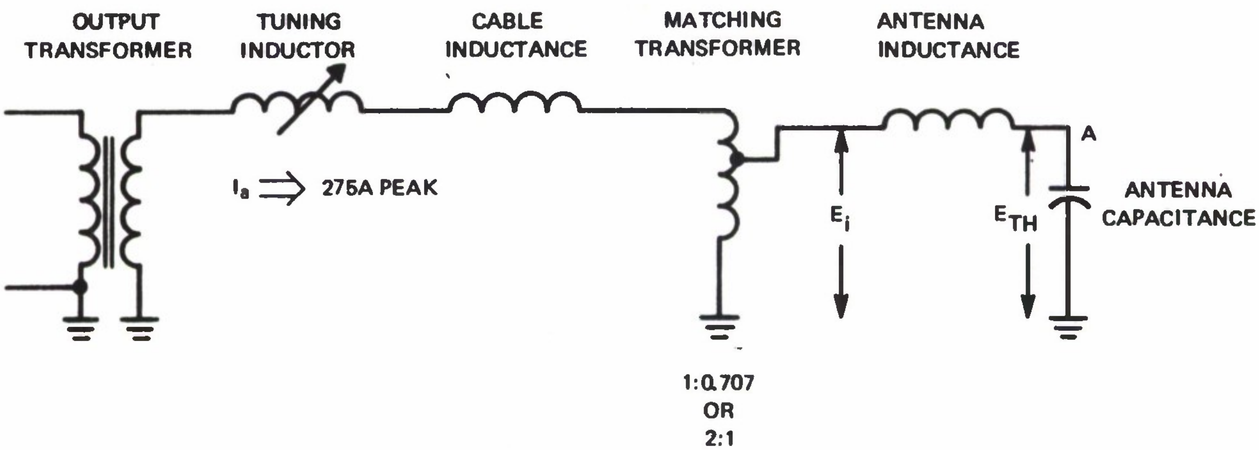


Figure 36. Antenna Tuning, Schematic Diagram

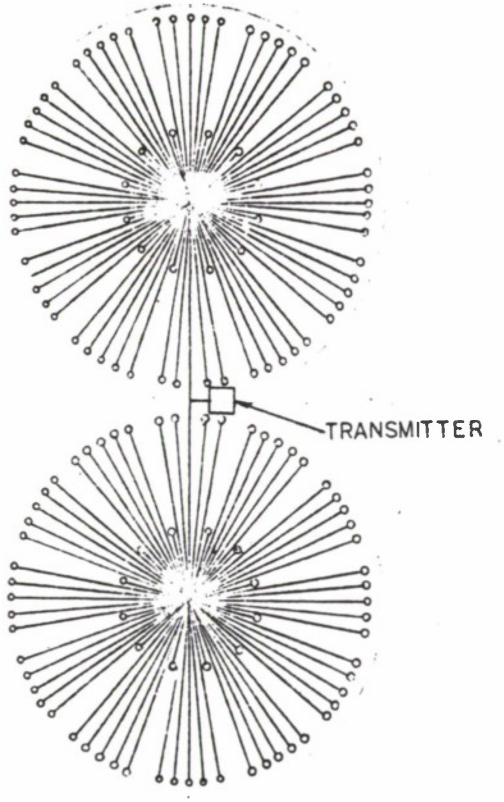


Figure 37. Two-Tower Array,

Configuration 15, Top View of Ground Plane

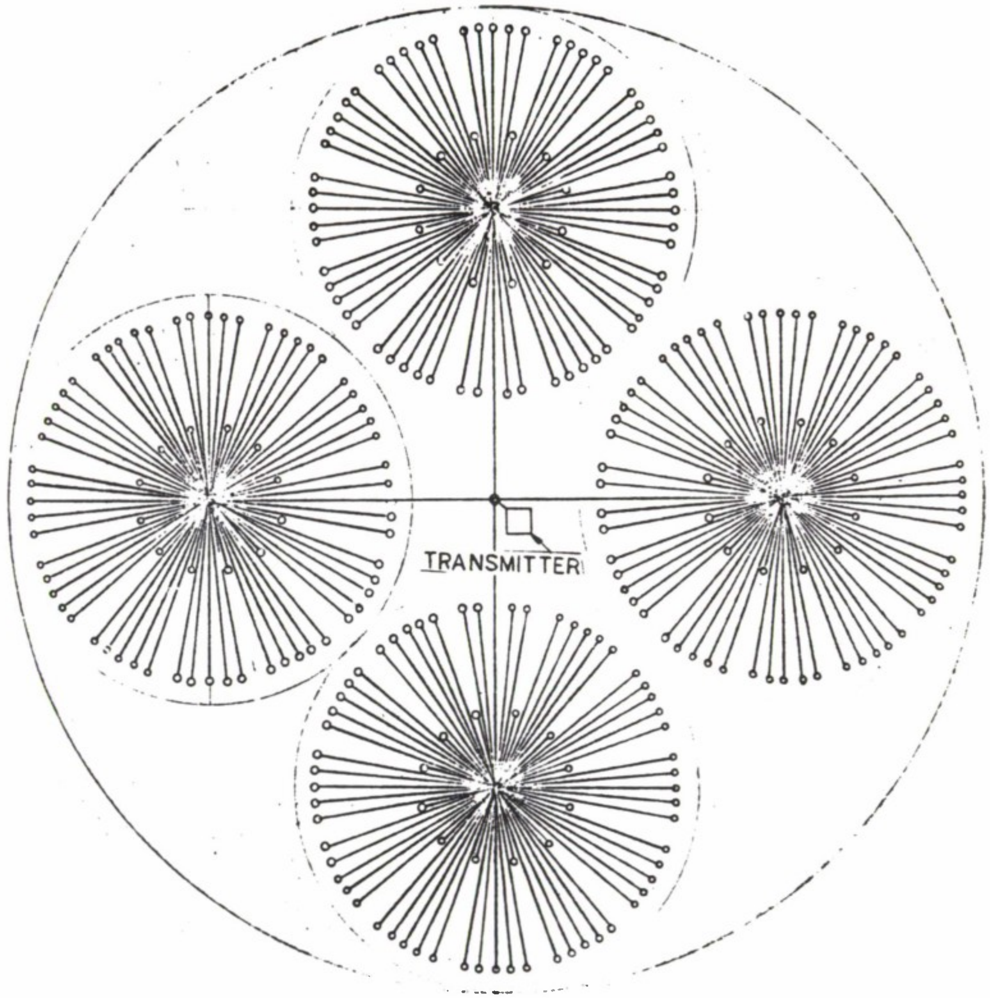


Figure 38. Four-Tower Array,

Configurations 29 and 32, Top View of Ground Plane

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